

**WATER LEVEL STATION
SPECIFICATIONS AND DELIVERABLES
FOR
SHORELINE MAPPING PROJECTS**

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**Center for Operational Oceanographic Products and Services
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1. Tides and Water Levels Requirements

1.1 General Project Requirements and Scope

1.1.1 Scope

The requirements and specifications contained in this section cover the water level and tidal datum requirements for the operational support of the remote sensing surveys conducted as part of the NOAA National Geodetic Survey (NGS) Coastal Mapping Program (CMP). The scope of this support is comprised of the following functional areas:

1. Tide and water level requirements planning
2. Tidal zoning development
3. National Water Level Observation Network (NWLON) control water level station operation, monitoring, and maintenance
4. Subordinate water level station installation, operation, monitoring, maintenance, and removal
5. Data quality control, processing, and tabulation
6. Tidal datum computation and tidal datum recovery
7. Quality control check and data validation of contractor submitted data to CO-OPS

For NGS in-house CMP surveys, personnel from the NOAA's National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) are responsible for functional areas 1, 2, 3, 5, and 6. CO-OPS, NGS, or CO-OPS or NGS selected contractors may install, maintain, and remove the gauges, but CO-OPS will be responsible for monitoring and operation of the water level gauges.

For NGS contract CMP surveys, CO-OPS personnel are responsible for functional areas 1, 2, 3 and 7. NGS contract personnel shall be responsible for functional areas 4 through 6 above. CO-OPS will be responsible for operating, maintaining, and processing data from the National Water Level Observation Network (NWLON) control stations.

1.1.2 Objectives

The work performed according to the requirements and specifications of this document is required for shoreline mapping and aerial photogrammetry products and services. The first objective is to provide the tidal predictions and tidal zoning so that flight windows can be determined. The second objective is to ensure remotely sensed data can be collected at the proper stages of the tide (Mean High Water (MHW) plus or minus tolerances, and Mean Lower Low Water (MLLW) plus or minus tolerances) as per the NGS CMP Statement of Work (SOW) specifications based upon the tidal zoning. A third objective is to establish and/or recover tidal datums, connect to geodetic datums where possible, and connect to NSRS and ellipsoid via GPS observations on a tidal or geodetic bench mark. A fourth objective is to provide new information or updated information that can be used to update tide prediction tables, produce or update shoreline mapping products, support coastal resource management, and support marine engineering applications. A fifth objective is to verify the tidal data so that the imagery can be

checked to ensure the tolerances were met. The products derived support the NOAA strategic goals of Commerce and Transportation, Weather and Water, and Ecosystem and Climate.

1.1.3 Planning and Tidal Zoning

CO-OPS is responsible for all planning of tide and water level requirements for NOS Coastal Mapping Program surveys. CO-OPS will analyze historical data and tidal characteristics for each project area, specify control water level stations, specify subordinate water level station locations to be installed, and provide the tidal zoning to be used during shoreline mapping surveys. CO-OPS will provide 6-minute interval tide predictions relative to MHW and MLLW for appropriate NOS control stations prior to each survey and will also provide historical published bench mark information available for all historical tide stations specified for reoccupation. The definitions of MLLW and MHW are located at <http://tidesandcurrents.noaa.gov/publications/glossary2.pdf>

1.1.4 NOS Control Stations and Data Quality Monitoring

1.1.4.1 National Water Level Observation Network (NWLON)

CO-OPS manages the NWLON of approximately 205 (as of October 2008) continuously operating water level observation stations in the U.S. coastal zone, including the Great Lakes. As most of these stations are equipped with satellite radios, near real-time (within about 30 minutes of collection) preliminary data are made available to all users through the CO-OPS Web page at <http://tidesandcurrents.noaa.gov>. Verified products, such as edited 6-minute data, hourly heights, high and low waters, and monthly means are made available over the Web within one to four weeks after data collection for NWLON stations. Accepted tidal datums relative to the National Tidal Datum Epoch (NTDE) are also available on the web. NWLON data and accepted tidal datums are used to provide tide reducers, control for tidal zoning, and for control for datum determination at subordinate (short-term) stations. Preliminary and verified data are made available over the Web relative to MLLW, or MHW datum, station datum, or special water level datum (such as Columbia River datum) as a user option in the interface.

1.1.4.2 Data Quality Monitoring

CO-OPS has an in-place Continuous Operational Real-Time Monitoring System (CORMS) that provides quality control and system monitoring functions on a 24 hour/day, 7 days/week, all year around basis for CO-OPS monitored gauges. CORMS will monitor the status and performance of all in-house water level gauges equipped with satellite radios using the NOS satellite message format and that are installed by either CO-OPS, or CO-OPS contractors for NOS in-house 1 shoreline mapping projects only, and once these gauges are listed on the Hydro Hot List (HHL) by CO-OPS. CORMS monitors all NOS water level systems, including all NWLON stations. HHL is a web based list where real time preliminary water level data for selected stations is made available to users. HHL lists water level gauges that are configured in CO-OPS Database Management System (DMS).

For shoreline mapping contract surveys, the contractor is responsible for all data monitoring, repairs, and ensuring the proper gauge operation of the subordinate stations.

1.1.5 General Data and Reference Datum Requirements

The present NOAA Nautical Chart Reference Datum for soundings for tidal waters is MLLW (see: *Tide and Current Glossary*, at <http://tidesandcurrents.noaa.gov/publications/glossary2.pdf>) based on the latest NOAA National Tidal Datum Epoch (NTDE) of 1983-2001. The present NOAA shoreline reference datum is MHW. All tidal datum computations and water level reductions for shoreline surveys shall be referenced to these datums. In non-tidal areas, including the Great Lakes, special low water datums have been defined for specific areas and are used as chart datum in these locations. In some cases where historical sites are re-occupied, site datum shall be zeroed to a pre-established MLLW datum held on a bench mark. In that case, data can be acquired relative to MLLW for immediate application during the survey.

For non-tidal areas such as the Great Lakes areas, a unique Low Water Datum (LWD) for each lake relative to International Great Lakes Datum of 1985 (IGLD 85) is the reference datum. In other non-tidal coastal areas, LWD is determined by subtracting 0.5 ft from Mean Water Level (MWL) (equivalent to Mean Sea Level (MSL)) observed at the water level stations.

1.1.6 Error Budget Considerations

The accuracy of measuring shoreline can vary significantly depending upon the slope the coastline. The error for estimating the shoreline (horizontal location of MHW or MLLW intersects the shore) is reduced for steep slope of coastline, whereas for areas of flat coastline the error for estimating the shoreline is increased.

The following table provides potential horizontal displacements of boundary positions resulting from errors in vertical datum determinations

Error in datum (in meters and feet)	Horizontal Displacement of Boundary for Beach Slope of Angle with Horizontal as listed below (in meters & feet)		
	30 degrees	10 degrees	1 degree
0.61 m (2.0 ft)	1.05 m (3.46 ft)	3.46 m (11.34 ft)	34.92 m (114.58 ft)
0.91 m (1.5 ft)	0.79 m (2.60 ft)	2.59 m (8.51 ft)	16.19 m (85.94 ft)
0.30 m (1.0 ft)	0.52 m(1.73 ft)	1.73 m (5.67 ft)	17.46 m (57.29 ft)
0.15 m (0.5 ft)	0.26 m (0.87 ft)	0.86 m (2.84 ft)	8.72 m (28.64 ft)
0.03 m (0.1 ft)	0.05 m (0.17 ft)	0.17 m (0.57 ft)	1.74 m (5.73 ft)

What the table shows is that the horizontal displacement is the largest for a flat beach slope. The errors demonstrated in this table in turn drive the operational error budgets described in the next paragraph.

According to NGS Scope of Work (Attachment J – Tide Coordination Requirements), the imagery shall be obtained within a tolerance as specified of MHW and MLLW to determine the shoreline. When the mean range of the tide station is 5 feet (1.5 m) or less the tolerance is +/- 0.3 feet (0.1 m), and when the mean range of the tide station is greater than 5 feet (1.5 m), the tolerance is +/- 10% of the mean range. So the MHW +/- tolerance creates time windows during

which the imagery needs to be obtained for high water shoreline, and MLLW +/- tolerance creates time windows during which the imagery needs to be obtained for the low water shoreline.

In order to meet these error and tolerance targets, the allowable contribution of the error for tides and water levels is estimated between 0.20 m and 0.45 m (at the 95% confidence level) depending on the complexity of the tides. These numbers were developed from NOS internal study for hydrographic surveys and are applicable whenever tidal zoning is used for shoreline mapping projects.

The total error of the tides and water levels can be considered to have component errors of:

1. The measurement error of the gauge/sensor and processing error to refer the measurements to station datum. Gauges/sensors need to be calibrated, and sensor design and data sampling need to include strategies to reduce measurement errors due to waves, currents, temperature, and density effects. The measurements need to be properly referenced to the bench marks and tide staffs, as appropriate and monitored for vertical stability. The measurement error, including the dynamic effects, should not exceed 0.10 m at the 95% confidence level. The processing error also includes interpolation error of the water level at the exact time of the imagery. An estimate for a typical processing error is 0.10 m at the 95% confidence level.
2. The error in computation of tidal datums for the adjustment to an equivalent 19-year National Tidal Datum Epoch (NTDE) periods for short term stations. The shorter the time series, the less accurate the datum, i.e. bigger the error. An inappropriate control station also decreases accuracy. The NTDE does not apply in the Great Lakes, however the accuracy of datum based on shorter time series is analogous. The estimated error of an adjusted tidal datum based on one month of data is 0.08 m for the east and west coasts and 0.11 m for the Gulf coast (at the 95% confidence level).
3. The error in application of tidal zoning. Tidal zoning is the extrapolation and/or interpolation of tidal characteristics from a known shore point(s) to a desired survey area using time differences and range ratios. The greater the extrapolation/interpolation, the greater the uncertainty and error. Estimates for typical errors associated with tidal zoning are 0.20 m at the 95% confidence level. However, errors for this component can easily exceed 0.20 m if tidal characteristics are very complex, or not well-defined, and if there are pronounced differential effects of meteorology on the water levels across the survey area.

Project planning by NOS attempts to minimize and balance these potential sources of errors through the use and specification of accurate and reliable water level gauges, optimization of the mix of zoning required, the number and locations of water level gauges required, and the length of observations required within practical limits of the survey area and survey duration. The practical limits depend upon the tidal characteristics of the area and suitability of the coastline for the installation and operation of appropriate water level stations.

1.2 Data Collection and Field Work

Continuous and valid water level data series are required. Accurate datums cannot be computed for a month of data with a break in the water level measurement series in excess of three days. Even breaks of significantly less than three days duration will not allow for interpolation during times when strong meteorological conditions are present and in areas with little periodic tidal influence. Any break in the water level measurement series affects the accuracy of datum computations. At each measurement site where the water level measurement data cannot be transmitted or monitored during the survey operations, an independent backup sensor or a complete redundant water level collection system shall be installed and operated during the project.

1.2.1 Water Level Station Requirements

Data from NWLON stations will be provided to support the both in-house and contract shoreline mapping survey operations. Tidal Predictions are also made available for NWLON stations on CO-OPS web page. Tidal predictions for historic subordinate stations can also be made available if CO-OPS has the historical tide station information.

The acquisition of water level data from subordinate locations may be required for shoreline mapping surveys and if so shall be specified by NOS in each individual set of Project Instructions. These stations shall be used to provide 6-minute time series data, tidal datum references and tidal zoning which all factor into the production of final tide reducers for specific survey areas. Station locations and requirements may be modified after station reconnaissance or as survey operations progress. Any changes shall be made only after consultation between the CO-OPS and Chief, Remote Sensing Division (RSD) (and COTR if contract survey) as relocating the required stations to new locations may require assignment of new seven-digit station identifier numbers, and new/historical station and bench mark information.. CO-OPS may not have adequate information to correctly determine the tides at new tide gauge location and that may affect the availability of tide predictions.

The duration of continuous water level data acquisition shall be a 30-day minimum. Water level data acquisition shall be from at least 4 hours before the beginning of the shoreline mapping survey operations to 4 hours after the ending of shoreline mapping survey operations, and/or shoreline verification in the applicable areas.

1.2.2 Water Level Measurement Systems and Data Transmissions

1.2.2.1 Water Level Sensor and Data Collection Platform

The water level sensor shall be a self-calibrating air acoustic, pressure (vented), or other suitable type that is approved by CO-OPS. The sensor measurement range shall be greater than the expected range of water level. Gauge/sensor systems shall be calibrated prior to deployment, and the calibration shall be checked after removal from operations. The calibration standard's accuracy must be traceable to National Institute of Standards and Technology (NIST). The required water level sensor resolution is a function of the tidal range of the area in which

shoreline mapping surveys are planned. For tidal range less than or equal to 5 m, the required water level sensor resolution shall be 1 mm or less; for tidal range between 5 m and 10 m, the required water level sensor resolution shall be 3 mm or less; and for tidal range greater than 10 m, the required water level sensor resolution shall be 5 mm or less.

The Data Collection Platform (DCP) shall acquire and store water level measurements every 6-minutes. The water level measurements shall consist of an average of at least three minutes of discrete water level samples with the period of the average centered about the six minute mark (i.e. :00, :06, :12, etc.). In addition to the average measurement, the standard deviation of the discrete water level samples which comprise the 6-minute measurements shall be computed and stored. The 6-minute centered average water level data is required for compatibility with the NWLON stations, and the standard deviation provides valuable data quality information regarding each measurement. The clock accuracy of a satellite radio system shall be within 1 second per month so that channel “stepping” does not occur. Non-satellite radio systems shall have a clock accuracy of within one minute per month. Known error sources for each sensor shall be handled appropriately through ancillary measurements and/or correction algorithms. Examples of such errors are water density variations for pressure gauges, sound path air temperature differences for acoustic systems, and high frequency wave action and high velocity currents for all sensor types.

The NOS is currently using the Aquatrak® self-calibrating air acoustic sensors at the majority of the NWLON stations. (For further information refer to *Next Generation Water level Measurement System (NGWLMS) Site Design, Preparation, and Installation Manual*, NOAA/NOS, January 1991, which is available at CO-OPS web page at the following url: (<http://tidesandcurrents.noaa.gov/publications/NextGenerationWaterLevelMeasurementSystemMANUAL.pdf>) and *User’s Guide for 8200 Acoustic Gauges*, NOAA/NOS, Updated August 1998 which is available at http://tidesandcurrents.noaa.gov/publications/hy8200aco_manual.pdf).

At stations where the acoustic sensor can not be used due to freezing or the lack of a suitable structure, either a ParoScientific intelligent pressure (vented) sensor incorporated into a gas purge system, or a well/float with absolute shaft angle encoder (Great Lakes Stations) are used by NOS for water level measurements. (For further information refer to *User’s Guide for 8200 Bubbler Gauges*, NOAA/NOS, Updated February 1998 which is available at CO-OPS web page at the following url: http://tidesandcurrents.noaa.gov/publications/hy8200bub_manual.pdf). Also refer to *User’s Guide for 8210 Bubbler Water Level Gauge for Hydrographic Surveying Applications (Installation and Operation)* February 2001 which is available at CO-OPS web page at the following URL: http://tidesandcurrents.noaa.gov/publications/8210_guide.pdf

When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle (minimum 3 hours) is required, see Section 1.2.4.2 Staff Observations for further details. Along with the averaging procedure described above which works as a digital filter, NOS uses a combination protective well/parallel plate assembly on the acoustic sensor and a parallel plate assembly (with 2" orifice chamber) on the bubbler orifice sensor to minimize systematic measurement errors due to wave effects and current effects, as shown in [Figure 1.1](#).

When pressure sensors are used to collect the water level data, orifice should be mounted on vertical surface such as piling of a wharf so that precise elevation of orifice below a staff stop

can be measured with a steel tape, and the elevation of the staff stop can be measured via differential leveling to the nearest benchmark and with the primary bench mark. If the orifice is mounted vertically and its elevation can be determined precisely with reference to the primary bench mark, then staff to gauge readings may not be necessary, and the requirement for staff to gauge readings may be waived. If the orifice can not be mounted to a vertical surface i.e. if the elevation of the orifice can not be determined precisely with the primary bench mark, then staffs to gauge readings are required to relate the water level datums to the bench marks. Refer to Section 1.2.4.1 for further discussion.

1.2.2.2 Data Transmissions

The data transmissions requirements are applicable where CO-OPS is monitoring the gauges as described in Section 1.1.4.2 Data Quality Monitoring above. The ability to monitor water level measurement system performance for near real-time quality assurance is essential to properly support shoreline mapping operations. Therefore, it is required that, where access to the satellite is available, the measurement system shall be equipped with a GOES transmitter to telemeter the data to NOS every three hours, hourly, or every 6 minutes. The data transmissions must use a message format identical to the format as currently implemented in NOS' Next Generation Water Level Measurement Systems (NGWLMS). This is required to assure direct compatibility with the NOS Data Management System (DMS). This data format is detailed in the reference document "NGWLMS GOES MESSAGE FORMATTING" (refer to Section 1.6 for Guidelines and References) and is available at CO-OPS web page at the following URL:

http://tidesandcurrents.noaa.gov/publications/newgoes_format.pdf. Once the station and gauge information is configured in DMS and station listed on the Hydro Hot List (HHL), (which is available at CO-OPS web page at the following url:

<http://tidesandcurrents.noaa.gov/hydro.shtml>) the NOS Continuous Operational Real-Time System (CORMS) will monitor all water level measurement system GOES transmissions to assure they are operating properly, provided that the GOES data transmitted is compatible with NOS format and CO-OPS is responsible for the operation of the gauge. Data that is not transmitted by GOES, or data transmitted but not in NOS compatible GOES format, or is submitted to CO-OPS on electronic formats currently used such as, CD-ROM, DVD-ROM or such other digital media, must also conform to the format specified in the above document so that data can be loaded properly into DMS software. Refer to Section 1.5.2 for further details about the water level data format specifications.

Close coordination is required between NGS personnel, installer, and the Operational Engineering Team (OET) of the Engineering Division (ED) of CO-OPS for all NOAA in-house shoreline mapping survey projects that have satellite transmission capability for water level installations. NOS will assist in acquiring assigned platform ID's, time slots, etc. for NGS in-house shoreline mapping projects. At least three business days prior to the installation of the tide gauge in the field, information about the station number, station name, latitude, longitude, platform-ID, transmit time, channel, and serial numbers of sensors, and DCP shall be faxed (telephone 301-713-4465), phoned (telephone 301-713-2897), or e-mailed (nos.coops.oetteam@noaa.gov) or mailed to ED. Test transmissions conducted on site are outside this requirement. This station and DCP information must be configured in DMS before data transmissions begin so that the all data will be accepted in DMS. The documentation required prior to transmission in field is defined in the NGWLMS Site Report, or Tide Station

Report, or Xpert Site Report, as appropriate. (Refer to Section 1.5 Data Submission Requirements).

1.2.3 Station Installation, Operation and Removal

Installer shall obtain all required permits and permissions for installation of the water level sensor(s), Data Collection Platforms (DCP), bench marks, and utilities, as required. The installer shall be responsible for security and/or protective measures, as required. The installer shall install all components in the manner prescribed by manufacturer, or installation manuals. The installer shall provide CO-OPS the position of all tide gauges installed, before the shoreline mapping survey begins, or during the survey, including those that were not specified in the Project Instructions, as appropriate. The positions of bench marks, sensors, and DCP installed or recovered shall be obtained and reported as latitudes and longitudes (degrees, minutes, seconds and tenth of seconds).

The water level station and its various components (tide house, DCP, all sensors, bench marks, and pertinent access facilities such as railings, steps, etc., as appropriate), when designed or installed by contractors, shall be installed and maintained as prescribed by manufacturers, installation manuals, appropriate local building codes, or as specified by the Contracting Officer's Technical Representative (COTR), if applicable. Water level station and all installed components shall be structurally sound for its intended application, secure, and safe to use for NOS, local partners, contractors, and general public, as appropriate.

The following paragraphs provide general information regarding requirements for station installation, operations and maintenance, and station removal.

1.2.3.1 Station Installation

A complete water level measurement gauge installation shall consist of the following:

- A. The installation of the water level measurement system (water level sensor(s), DCP, and satellite transmitter, as appropriate) and its supporting structure and a tide staff, if required.
- B. The recovery and/or installation of a minimum number of bench marks and a level connection between the bench marks and the water level sensor(s), and tide staff as appropriate. The required minimum number of bench marks are specified in the "User's Guide for the Installation of Bench marks and Leveling Requirements for Water Level Stations, NOAA/NOS, dated October 1987.
- C. The preparation of all documentation and forms. (See Section 1.5.3)

1.2.3.2 Operation and Maintenance

When GOES telemetry and NOS satellite message format is used for NOS in-house shoreline mapping surveys, the installer shall monitor the near-real time water level gauge data daily for indications of sensor malfunction or failure, and for other causes of degraded or invalid data,

such as marine fouling. This monitoring can be performed by accessing the COOPS web page (<http://TidesandCurrents.noaa.gov>). The data over this system are typically available for review within one to four hours after collection.

All repairs, adjustments, replacements, cleaning, or other actions potentially affecting sensor output or collection of data shall be documented in writing using appropriate maintenance forms (see Section 1.5.1 on water level station documentation below) and retained as part of the water level data record. This documentation shall include, but not be limited to, the following information: date and time of start and completion of the maintenance activity; date and time of adjustments in sensor/DCP, datum offset, or time; personnel conducting the work; parts or components replaced; component serial numbers; tests performed; etc.

For water level stations that are collecting data for more than six months duration, a check level is required at every six month duration from the installation of the gauge till the water level gauge is removed. See Section 1.2.5.4 Leveling Frequency for further details.

1.2.3.3 Removal

A complete removal of the water level measurement gauge shall consist of the following:

- A. Closing levels - a level connection between the minimum number of required bench marks and the water level sensor(s) and tide staff as appropriate.
- B. Removal of the water level measurement system and restoration of the premises, reasonable wear and tear accepted.
- C. The preparation of all documentation, forms, data, and reports. (See Section 1.5.3)

1.2.4 Tide Staffs, Staff Observations, and Bubbler/Pressure Sensor Orifice

1.2.4.1 Staff

The installer shall install a tide staff at a station if the reference measurement point of a sensor (zero of a gauge) cannot be directly leveled to the local bench marks (e.g. orifice/pressure sensor has to be installed offshore on the sea floor). The tide staff is generally not required for acoustic gauges because the sensor elevation (the sensor zero reference point) can be measured during leveling. Even if a pressure gauge sensor elevation (the sensor zero reference point) can be leveled directly, staff readings shall still be required for assessment of variations in gauge performance due to density variations in the water column over time. The tide staff shall be mounted independent of the water level sensor so that stability of the staff or sensor is maintained. Staff shall not be mounted to the same pile on which the water level sensor is located. The staff shall be plumb. When two or more staff scales are joined to form a long staff, the installer shall take extra care to ensure the accuracy of the staff throughout its length. The distance between staff zero and the rod stop shall be measured before the staff is installed and after it is removed and the rod stop above staff zero height shall be reported on the documentation forms including leveling abstracts.

In areas of large tidal range and long sloping beaches (i.e. Cook Inlet, AK, and the Gulf of Maine), the installation and maintenance of tide staffs can be extremely difficult and costly. In these cases, the physical installation of a tide staff(s) may be substituted by systematic leveling to the water's edge from the closest bench mark. The bench mark becomes the "staff stop" and the elevation difference to the water's edge becomes the "staff reading".

1.2.4.2 Staff Observations

When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle (minimum 3 hours) shall be required (1) at the start of water level data collection, (2) at frequent intervals during deployment, and (3) at the end of a deployment before gauge has been removed. Frequent gauge/staff comparisons during deployment shall be required to assist in assuring measurement stability and minimizing processing type errors. The staff to gauge observations at the start and end of deployment shall be at least each three hours long and the periodic observations during the deployment shall be at least 1 hour long. The staff to gauge observations shall be performed three times per week, during each week of the project, with at least one hour long observations of 6 minute intervals for each time. Where staff to gauge observations can not be performed three times a week as required then an explanation is required for the deficiency of number of observations and staff to gauge observations shall be performed at least (a) minimum eight times spread out over each month (e.g. two times per week) and at each time at least 1 hour of observations at 6 minute interval, or (b) minimum of four times spread out over each month (e.g. one time per week) and at each time at least 2 hours of observations at 6 minute interval, whichever is convenient.

The staff to gauge differences should remain constant throughout the set of observations and show no increasing or decreasing trends. If the staff to gauge differences do not remain constant, then collected water level data may not be valid for deriving datums. After the water level data has been collected, the averaged staff-to-gauge shall be applied to water level measurements to relate the data to staff zero. A higher number of independent staff readings decrease the uncertainty in transferring the measurements to station datum and the bench marks. Refer to [Figure 1.2](#) for an example pressure tide gauge record.

If a tide staff is found destroyed by elements during the deployment, then a new staff shall be installed for the remainder period of the deployment and a new staff to gauge constant needs to be derived by new sets of staff to gauge observations. Also when a staff or an orifice is replaced or re-established, check levels shall be run to minimum of three bench marks including the Primary Bench Mark (PBM). Refer to Section 1.2.5 for leveling frequency and other leveling requirements.

For water level historic stations that are reoccupied, CO-OPS will provide the station datum (SD) information for the station. This information is generally given for the PBM above the historic SD. In that case, for pressure sensors that require staff-to-gauge observations, all the water level data shall be placed on the station datum using the following equation:

Water level data on the SD = (Preliminary pressure water level data on an arbitrary datum as collected by the gauge) + (PBM above SD) - (Staff zero below PBM) - (+/- weighted staff-to-gauge constant)

Staff zero below PBM = (Staff stop below PBM) + (Staff zero below Staff stop)

The staff to gauge constant shall be derived as a weighted average of all the staff to gauge readings done for the project, and staff to gauge constant shall be applied algebraically (with proper sign). The staff zero below PBM is obtained generally by (a) leveling from PBM to staff stop and (b) then measuring the staff stop to staff zero elevation with a steel tape and (c) then combining the two (a and b) elevation values. The staff zero below PBM is obtained by averaging the elevations differences during the opening (installation) and closing (removal) leveling runs for short term occupations.

The orifice elevation above station datum is also defined as an accepted orifice offset in CO-OPS Data Management System (DMS).

1.2.4.3 Bubbler Orifice and Parallel Plate Assembly

This bottom assembly is made of red brass; its chemical properties prevent the growth of marine life by the slowly releasing copper oxide on its metal surface. A Swagelok® hose fitting is screwed into the top end cap and is used to discharge the Nitrogen gas. The Nitrogen gas flows through the bottom of the orifice at a rate sufficient to overcome the rate of tidal change and wave height. This opening establishes the reference point for tidal measurements. The parallel plates produce a laminar flow across the orifice to prevent the venturi effect. A two inch by eight inch pipe (as shown here) provides the correct volume gas for widest range of surf conditions encountered by most coastal surveys.

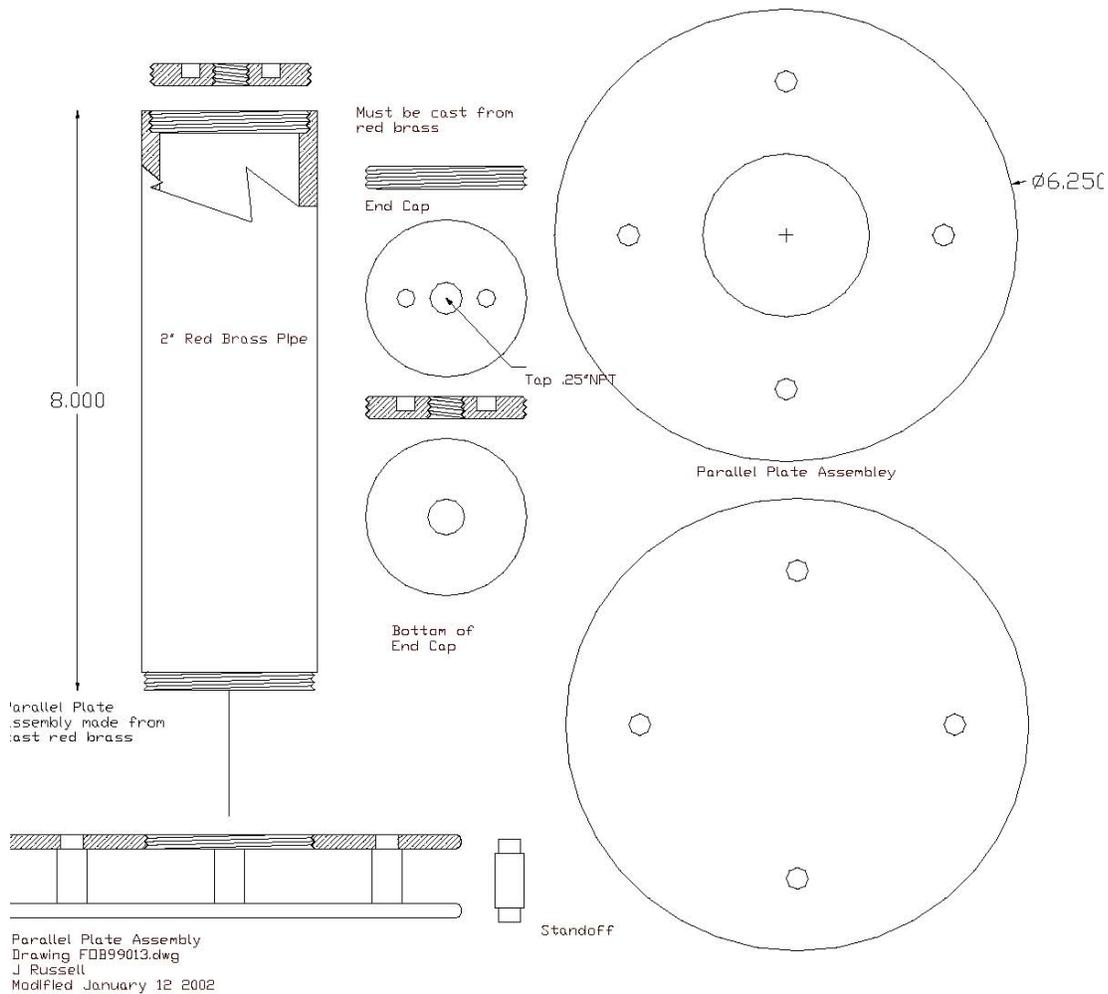


Figure 1.1. Bubbler Orifice Bottom Assembly

1.2.5 Bench Marks and Leveling

1.2.5.1 Bench Marks

According to NGS Geodetic Glossary a bench mark is a relatively permanent, natural or artificial, material object bearing a marked point whose elevation above or below an adopted surface (datum) is known. A bench mark is set for stability and used as a reference to the vertical and/or horizontal datums.

Bench marks in the vicinity of a water level measurement station are used as the reference for the local tidal datums derived from the water level data. The relationship between these tidal bench marks and the water level sensor or tide staff shall be established by differential leveling.

1.2.5.2 Number and Type of Bench Marks

The number and type of bench marks required depends on the duration of the water level measurements. The *User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations*, dated October 1987, which is available at the following URL: http://tidesandcurrents.noaa.gov/publications/users_guide_for_installation_of_Bench_Mark.pdf specifies the installation and documentation requirements for the bench marks. Each water level station will have one bench mark designated as the PBM, which shall be leveled to on every run. The PBM is typically the most stable mark in close proximity to the water level measurement station. The contractor shall select a PBM at sites where the PBM has not already been designated. For historic water level station reoccupations, CO-OPS will furnish the designation/stamping of the PBM and PBM elevation above station datum, if available.

The most desirable bench mark for GPS observations will have 360 degrees of horizontal clearance around the mark at 10 degrees and greater above the horizon and stability code of A or B. Refer to *User's Guide for GPS Observations At Tide and Water Level Station Bench Marks*, Updated November 2008 which is available at the following URL: <http://tidesandcurrents.noaa.gov/pub.html> for further information.

If the PBM is determined to be unstable, another mark shall be designated as PBM. The date of change and the elevation difference between the old and new PBM shall be documented. NOAA will furnish the individual NOS standard bench mark disks to be installed. Bench mark descriptions shall be written according to *User's Guide for Writing Bench Mark Descriptions*, updated January 2003 (<http://tidesandcurrents.noaa.gov/publications/bmguid5.pdf>).

1.2.5.3 Leveling

At least, geodetic third-order levels (refer to Reference 19, but 2nd order class I levels are preferred) shall be run at short-term subordinate stations operated for less than one-year. Requirements for higher order levels will be specified in individual project instructions, or statements of work, as appropriate. Standards and specifications for leveling are found in *Standards and Specifications for Geodetic Control Networks and Geodetic Leveling (NOAA Manual NOS NGS 3)* (http://www.ngs.noaa.gov/PUBS_LIB/Geodeticleveling_nos_3.pdf). Additional field requirements and procedures used for leveling at tide stations can be found in

the *User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations*. Electronic digital/barcode level systems are preferable.

Specifications and standards for digital levels can be found in *Standards and Specifications for Geodetic Control Networks* (http://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.htm#3.5) and additional field requirements and procedures used by NOS for electronic leveling at water level stations can be found in the *User's Guide for Electronic Levels, updated January 2003*, which is available at the following url: <http://tidesandcurrents.noaa.gov/publications/laserlevelsguide.pdf>.

1.2.5.4 Leveling Frequency

Levels shall be run between the water level sensor(s) or tide staff (depending on the type of gauge) and the required number of bench marks when the water level measurement station is installed, modified (e.g., water level sensor serviced, staff, or orifice replaced), for time series bracketing purposes, or prior to removal. In any case, levels are required at a maximum interval of six (6) months during the station's operation, and are required after severe storms, hurricanes, or earthquakes to document stability (see stability discussed below).

1.2.5.5 Stability

If there is an unresolved movement of the water level sensor or tide staff zero relative to the PBM, from one leveling to the next, of greater than 0.006 m, the leveling party shall verify the apparent movement by re-running the levels between the sensor zero or tide staff to the PBM and all the marks. The confirmation levels provide verification that sensor/bench mark indeed moved, or did not move. Since short term water level gauges generally do not have long term leveling history as do the NWLON permanent water level gauges, hence, the confirmation levels provide information that can be used to verify sensor/bench mark stability during the data processing. This threshold of 0.006 m should not be confused with the closure tolerances used for the order and class of leveling.

1.2.6 Water Level Station Documentation

The field team shall maintain a documentation package for each water level measurement station installed for shoreline mapping projects. The documentation package shall be forwarded after a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station. Refer to time frames for submission of documentation in Section 1.5.3.

Generally, all documentation (see Section 1.5 for Data Submission Requirements) shall be forwarded when a station is installed. For other situations, only information that has changed shall be submitted (e.g., levels and abstract for bracketing or removal levels, NGWLMS Site Report, or Tide Station Report, or Xpert Site Report, as appropriate, for maintenance and repair or station removal, etc.) Refer to Section 1.5.3 for documentation requirements.

1.2.7 Additional Field Requirements

- A. Complete data set must be sent as a batch for short term station (less than 6 months duration) installed. For long term stations submit water level data every 6 months till the gauge is removed unless the data are transmitted via satellite. The 6 month submission shall also include updated hourly heights, high/ low, monthly means, and datums.
- B. All water level data from a gauge shall be downloaded and backed up on electronic formats currently used such as CD-ROM or DVD-ROM, whether the gauge data are sent via satellite or not.
- C. For new water level stations that do not have station numbers assigned, once the location of the gauge has been finalized, then contact CO-OPS or COTR and provide latitude and longitude of the gauge site at least three business days prior to actual installation of the gauge in field. CO-OPS will assign a new station number within three business days and inform the installer.
- D. At each water level station, GPS observations at one bench mark shall be performed according to the most recent version of CO-OPS' "User's Guide for GPS Observations At Tide and Water level Station Bench Marks"
(http://tidesandcurrents.noaa.gov/publications/Users_Guide_for_GPS_Observations_updated_November_2008.pdf).

1.3 Data Processing and Reduction

1.3.1 Data Quality Control

The required output product used in generation of tide control for the stage of tide and for tidal datum determination is a continuous time series of 6-minute interval water level data for the desired time period of survey and for a specified minimum time period from which to derive tidal datums. The 6-minute interval water level data from the water level gauges shall be quality controlled to NOS standards by the contractor for invalid and suspect data as a final review prior to product generation and submission to CO-OPS for data validation. This includes checking for data gaps, data discontinuities, datum shifts, anomalous data points, data points outside of expected tolerances such as expected maximum and minimum values and for anomalous trends in the elevations due to sensor drift or vertical movement of the tide station components and bench marks.

Quality control shall include comparisons with simultaneous data from backup gauges, predicted tides or data from nearby stations, as appropriate. Data editing and gap filling shall use documented mathematically sound algorithms and procedures, and an audit trail shall be used to track all changes and edits to observed data. All inferred data shall be appropriately flagged. Water level measurements from each station shall be related to a single, common datum, referred to as Station Datum. Station Datum is an arbitrary datum and should not be confused with a tidal datum such as MLLW or a geodetic datum such as NAVD 88. All discontinuities, jumps, or other changes in the gauge record (refer to the specific gauge user's guide) shall be fully documented. All data shall be recorded on Greenwich Mean Time (GMT) or Universal Time

Coordinated (UTC) and the metric units of measurement shall be properly denoted on all hard-copy output and digital files. Refer to Section 1.5 Data Submission Requirements for details.

Refer to Tidal Datums and Their Applications at http://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf and Computational Techniques for Tidal Datums Handbook at http://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf for additional information.

1.3.2 Data Processing and Tabulation of the Tide

The continuous 6-minute interval water level data are used to generate the standard tabulation output products. These products include the times and heights of the high and low waters, hourly heights, maximum and minimum monthly water levels, and monthly mean values for the desired parameters. Examples of these tabulation products are found in [Figure 1.3](#) and 1.4 for tide stations and [Figure 1.5](#) for Great Lakes stations. The times and heights of the high and low waters shall be derived from appropriate curve-fitting of the 6-minute interval data. For purposes of tabulation of the high and low tides and not non-tidal high frequency noise, successive high and low tides shall not be tabulated unless they are greater than 2.0 hours apart in time and 0.030 meters different in elevation. Hourly heights shall be derived from every 6-minute value observed on the hour. Monthly mean sea level and monthly mean water level shall be computed from the average of the hourly heights over each calendar month of data. Data shall be tabulated relative to a documented consistent station datum such as tide staff zero, arbitrary station datum, MLLW, etc., over the duration of the data observations. Descriptions of general procedures used in tabulation are also found in the *Tide and Current Glossary, Manual of Tide Observations, Tidal Datum Planes, and Computational Techniques for Tidal Datums Handbook*.

Refer to Tidal Datums and Their Applications at http://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf and Computational Techniques for Tidal Datums Handbook at http://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf for additional information.

1.3.3 Computation of Monthly Means

Monthly means are derived on a calendar month basis in accordance with the definitions for the monthly mean parameters as found in the Tide and Current Glossary. Examples of the desired monthly means are found in [Figure 1.7](#). For purposes of monthly mean computation, monthly means shall not be computed if gaps in data are greater than three consecutive days. For partial month (any data less than full month) water level data, perform tide by tide comparison with the control station data.

1.3.4 Data Editing and Gap Filling Specifications

When backup sensor data are not available, data gaps in 6-minute data shall not be filled if the gaps are greater than three consecutive days in length. Data gap filling shall use documented mathematically and scientifically sound algorithms and procedures and an audit trail shall be used to track all gap-fills in observed data. Data gaps of less than 3-hours can be inferred using interpolation, curve-fitting techniques, and predictions. Data gaps of longer than three hours but less than 3 days may use external data sources such as data from a nearby station, provided the data matches and there are no meteorological events during that gap. All data derived through gap-filling procedures shall be marked as inferred. Individual hourly heights, high and low waters, and daily means derived from inferred data shall also be designated as inferred.

HOURLY WATER LEVELS

National Ocean Service (NOAA)

July 1998

Water Level Heights in meters on Station Datum

Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY , CA																Time Meridian	0 W	Tide Type: Mixed
HOUR	Jul 1	Jul 2	Jul 3	Jul 4	Jul 5	Jul 6	Jul 7	Jul 8	Jul 9	Jul 10	Jul 11	Jul 12	Jul 13	Jul 14	Jul 15	Jul 16		
00	3.247	3.183	3.119	3.052	2.936	2.837	2.770	2.724	2.717	2.763	2.814	2.960	3.152	3.354	3.481	3.529		
01	3.329	3.333	3.319	3.274	3.157	3.066	2.972	2.851	2.762	2.694	2.637	2.723	2.901	3.162	3.365	3.517		
02	3.311	3.391	3.449	3.437	3.378	3.293	3.173	3.060	2.913	2.799	2.627	2.602	2.653	2.868	3.123	3.395		
03	3.164	3.312	3.463	3.526	3.526	3.504	3.423	3.298	3.171	2.988	2.750	2.618	2.529	2.621	2.792	3.103		
04	2.948	3.158	3.338	3.469	3.595	3.629	3.617	3.555	3.420	3.261	2.985	2.755	2.606	2.523	2.523	2.741		
05	2.725	2.914	3.091	3.304	3.474	3.628	3.714	3.707	3.652	3.519	3.247	3.012	2.757	2.576	2.423	2.459		
06	2.558	2.651	2.811	3.012	3.209	3.430	3.640	3.740	3.782	3.711	3.508	3.252	2.986	2.745	2.472	2.302		
07	2.528	2.451	2.531	2.651	2.833	3.112	3.342	3.580	3.746	3.785	3.668	3.485	3.217	2.954	2.619	2.399		
08	2.581	2.453	2.387	2.366	2.448	2.653	2.915	3.225	3.496	3.677	3.715	3.628	3.433	3.155	2.804	2.480		
09	2.648	2.510	2.375	2.228	2.133	2.243	2.435	2.701	3.060	3.348	3.540	3.626	3.535	3.354	2.997	2.651		
10	2.778	2.568	2.400	2.229	2.017	1.994	2.057	2.236	2.477	2.819	3.159	3.410	3.510	3.444	3.185	2.870		
11	2.890	2.696	2.494	2.280	2.057	1.909	1.859	1.919	2.081	2.327	2.576	2.970	3.257	3.389	3.283	3.040		
12	2.976	2.813	2.643	2.431	2.159	1.972	1.826	1.719	1.774	1.922	2.101	2.422	2.818	3.165	3.248	3.162		
13	2.995	2.917	2.750	2.581	2.327	2.124	1.913	1.756	1.674	1.667	1.781	2.000	2.350	2.735	3.051	3.175		
14	2.904	2.945	2.897	2.760	2.559	2.338	2.117	1.908	1.744	1.633	1.588	1.706	1.946	2.305	2.737	3.069		
15	2.742	2.903	2.922	2.898	2.778	2.611	2.387	2.154	1.944	1.759	1.625	1.612	1.732	1.965	2.365	2.831		
16	2.505	2.783	2.909	2.986	2.937	2.862	2.683	2.455	2.260	2.014	1.791	1.690	1.697	1.794	2.053	2.492		
17	2.359	2.594	2.814	2.976	3.040	3.034	2.954	2.786	2.585	2.366	2.084	1.911	1.852	1.854	1.971	2.258		
18	2.250	2.473	2.649	2.915	3.028	3.137	3.124	3.015	2.936	2.739	2.449	2.242	2.074	1.986	2.020	2.177		
19	2.272	2.401	2.550	2.773	2.960	3.099	3.190	3.187	3.141	3.021	2.814	2.618	2.419	2.256	2.193	2.269		
20	2.336	2.413	2.484	2.647	2.812	2.990	3.149	3.215	3.271	3.239	3.094	2.975	2.797	2.595	2.462	2.415		
21	2.508	2.514	2.527	2.637	2.690	2.843	2.999	3.128	3.251	3.310	3.275	3.220	3.131	2.954	2.781	2.677		
22	2.736	2.685	2.631	2.636	2.634	2.709	2.835	2.982	3.130	3.233	3.280	3.369	3.339	3.242	3.104	2.961		
23	2.965	2.912	2.814	2.752	2.703	2.700	2.688	2.779	2.916	3.063	3.177	3.322	3.422	3.417	3.336	3.284		
Mean	2.761	2.791	2.807	2.826	2.808	2.822	2.824	2.820	2.829	2.819	2.762	2.755	2.755	2.767	2.766	2.802		
HOUR	Jul 17	Jul 18	Jul 19	Jul 20	Jul 21	Jul 22	Jul 23	Jul 24	Jul 25	Jul 26	Jul 27	Jul 28	Jul 29	Jul 30	Jul 31			
00	3.514	3.373	3.180	2.993	2.778	2.625	2.586	2.678	2.821	3.048	3.228	3.317	3.411	3.444	3.438			
01	3.654	3.617	3.485	3.264	3.035	2.810	2.649	2.586	2.613	2.749	2.951	3.122	3.270	3.357	3.466			
02	3.620	3.720	3.720	3.573	3.322	3.071	2.848	2.682	2.573	2.590	2.680	2.834	3.030	3.195	3.394	Monthly		
03	3.427	3.686	3.818	3.785	3.641	3.379	3.133	2.884	2.694	2.576	2.550	2.625	2.735	2.937	3.148	Max HWL		
04	3.111	3.433	3.737	3.907	3.840	3.659	3.444	3.201	2.926	2.761	2.591	2.538	2.547	2.704	2.888	04:54/21		
05	2.704	3.048	3.487	3.775	3.898	3.849	3.697	3.460	3.206	2.978	2.759	2.586	2.487	2.523	2.660	3.903		
06	2.398	2.607	3.017	3.452	3.745	3.887	3.866	3.717	3.505	3.247	2.976	2.757	2.553	2.486	2.467			
07	2.215	2.254	2.539	2.948	3.376	3.678	3.851	3.828	3.704	3.501	3.210	2.928	2.697	2.545	2.448			
08	2.255	2.073	2.167	2.436	2.810	3.269	3.593	3.770	3.778	3.652	3.390	3.150	2.860	2.659	2.477	Monthly		
09	2.319	2.064	1.953	2.018	2.299	2.662	3.083	3.430	3.637	3.659	3.504	3.302	3.031	2.809	2.571	Min LWL		
10	2.483	2.155	1.884	1.806	1.896	2.146	2.526	2.942	3.284	3.486	3.479	3.358	3.144	2.948	2.725	14:24/11		
11	2.691	2.304	1.993	1.757	1.696	1.794	2.071	2.397	2.758	3.107	3.252	3.294	3.203	3.055	2.856	1.579		
12	2.876	2.544	2.195	1.877	1.664	1.603	1.743	1.981	2.282	2.618	2.907	3.090	3.119	3.107	2.975			
13	3.037	2.784	2.453	2.094	1.808	1.637	1.621	1.723	1.924	2.215	2.471	2.741	2.953	3.037	3.031			
14	3.088	2.995	2.738	2.387	2.076	1.816	1.662	1.644	1.740	1.919	2.149	2.402	2.658	2.905	2.975	Monthly		
15	3.038	3.104	2.978	2.738	2.434	2.122	1.918	1.797	1.762	1.827	1.956	2.144	2.396	2.676	2.908	Mean		
16	2.880	3.119	3.134	3.028	2.790	2.510	2.249	2.056	1.942	1.882	1.950	2.016	2.231	2.493	2.725	MSL		
17	2.621	3.011	3.191	3.220	3.078	2.887	2.646	2.422	2.219	2.117	2.061	2.118	2.218	2.398	2.595	2.816		
18	2.400	2.812	3.107	3.284	3.266	3.162	3.018	2.791	2.604	2.412	2.302	2.244	2.299	2.432	2.508			
19	2.323	2.600	2.938	3.179	3.300	3.316	3.273	3.162	2.978	2.775	2.615	2.496	2.465	2.490	2.527			
20	2.402	2.513	2.731	3.013	3.210	3.336	3.394	3.345	3.271	3.109	2.939	2.795	2.688	2.663	2.620			
21	2.554	2.550	2.605	2.755	3.012	3.214	3.345	3.401	3.415	3.335	3.215	3.075	2.963	2.884	2.766			
22	2.789	2.698	2.619	2.612	2.735	2.975	3.189	3.316	3.427	3.428	3.369	3.310	3.184	3.109	2.984			
23	3.073	2.920	2.760	2.631	2.613	2.707	2.912	3.118	3.300	3.400	3.407	3.429	3.373	3.308	3.178			
Mean	2.811	2.833	2.851	2.855	2.847	2.838	2.847	2.847	2.848	2.850	2.830	2.820	2.813	2.840	2.847			

[] denotes inferred water level values Data Status: Verified

Figure 1.4. Hourly Height Water Level Data for a Tide Station

HOURLY WATER LEVELS

National Ocean Service (NOAA)

July 1998

Water Level Heights in meters IGLD (1985)

Station: 9052030 Oswego, Lake Ontario , NY																
Time Meridian: 75 W Data Type: Great Lakes																
HOUR	Jul 1	Jul 2	Jul 3	Jul 4	Jul 5	Jul 6	Jul 7	Jul 8	Jul 9	Jul 10	Jul 11	Jul 12	Jul 13	Jul 14	Jul 15	Jul 16
01	75.21	75.21	75.19	75.18	75.19	75.17	75.15	75.17	75.17	75.20	75.21	75.21	75.20	75.17	75.17	75.17
02	75.25	75.21	75.19	75.19	75.22	75.14	75.17	75.16	75.19	75.19	75.20	75.22	75.18	75.17	75.18	75.16
03	75.26	75.21	75.19	75.17	75.19	75.18	75.18	75.16	75.16	75.19	75.21	75.19	75.18	75.18	75.15	75.17
04	75.25	75.20	75.19	75.20	75.21	75.18	75.17	75.16	75.17	75.20	75.21	75.18	75.17	75.18	75.16	75.16
05	75.25	75.21	75.20	75.19	75.21	75.18	75.17	75.20	75.20	75.18	75.21	75.20	75.19	75.17	75.19	75.16
06	75.25	75.21	75.19	75.20	75.20	75.19	75.17	75.16	75.19	75.20	75.20	75.20	75.17	75.17	75.14	75.15
07	75.25	75.20	75.19	75.19	75.19	75.17	75.18	75.20	75.20	75.19	75.21	75.20	75.18	75.17	75.14	75.17
08	75.24	75.21	75.19	75.21	75.20	75.17	75.17	75.14	75.19	75.20	75.22	75.20	75.19	75.15	75.18	75.15
09	75.24	75.21	75.19	75.20	75.19	75.19	75.16	75.17	75.18	75.18	75.22	75.20	75.19	75.18	75.16	75.14
10	75.24	75.20	75.19	75.18	75.19	75.18	75.16	75.20	75.17	75.20	75.22	75.22	75.18	75.18	75.17	75.16
11	75.23	75.19	75.17	75.18	75.20	75.18	75.15	75.15	75.19	75.20	75.22	75.20	75.19	75.18	75.16	75.15
12	75.22	75.21	75.18	75.18	75.17	75.17	75.17	75.16	75.17	75.19	75.22	75.20	75.18	75.18	75.17	75.16
13	75.22	75.20	75.18	75.19	75.18	75.16	75.16	75.15	75.17	75.18	75.21	75.19	75.19	75.17	75.16	75.16
14	75.23	75.20	75.19	75.21	75.18	75.19	75.14	75.15	75.16	75.18	75.20	75.22	75.17	75.17	75.18	75.17
15	75.22	75.21	75.17	75.19	75.17	75.15	75.14	75.18	75.17	75.19	75.20	75.18	75.18	75.17	75.17	75.17
16	75.21	75.20	75.19	75.18	75.19	75.16	75.18	75.18	75.17	75.19	75.19	75.19	75.17	75.16	75.16	75.16
17	75.21	75.20	75.20	75.21	75.20	75.17	75.17	75.18	75.17	75.19	75.20	75.18	75.17	75.17	75.17	75.15
18	75.22	75.20	75.20	75.21	75.21	75.20	75.18	75.18	75.15	75.17	75.20	75.18	75.16	75.15	75.16	75.16
19	75.21	75.20	75.19	75.21	75.19	75.19	75.18	75.20	75.18	75.22	75.19	75.19	75.17	75.16	75.16	75.17
20	75.20	75.22	75.19	75.25	75.19	75.17	75.18	75.18	75.20	75.22	75.20	75.20	75.16	75.16	75.16	75.13
21	75.20	75.18	75.18	75.15	75.19	75.19	75.15	75.19	75.22	75.18	75.21	75.19	75.18	75.16	75.15	75.17
22	75.21	75.20	75.17	75.17	75.19	75.18	75.19	75.17	75.23	75.20	75.21	75.19	75.18	75.18	75.15	75.13
23	75.20	75.19	75.17	75.24	75.19	75.16	75.18	75.19	75.22	75.22	75.21	75.17	75.18	75.16	75.17	75.13
24	75.21	75.20	75.17	75.20	75.18	75.17	75.17	75.19	75.18	75.21	75.21	75.18	75.18	75.15	75.16	75.15
Mean	75.23	75.20	75.19	75.19	75.19	75.18	75.17	75.17	75.18	75.20	75.21	75.19	75.18	75.17	75.16	75.16
HOUR	Jul 17	Jul 18	Jul 19	Jul 20	Jul 21	Jul 22	Jul 23	Jul 24	Jul 25	Jul 26	Jul 27	Jul 28	Jul 29	Jul 30	Jul 31	
01	75.17	75.17	75.14	75.12	75.13	75.14	75.11	75.16	75.14	75.11	75.09	75.07	75.07	75.10	75.09	
02	75.17	75.18	75.14	75.16	75.12	75.16	75.12	75.16	75.14	75.10	75.08	75.09	75.06	75.11	75.08	
03	75.16	75.19	75.15	75.15	75.11	75.16	75.12	75.15	75.13	75.10	75.08	75.06	75.06	75.10	75.08	Monthly
04	75.17	75.18	75.14	75.14	75.13	75.15	75.10	75.14	75.14	75.10	75.07	75.09	75.02	75.09	75.08	Max HWL
05	75.16	75.18	75.16	75.13	75.14	75.13	75.14	75.16	75.13	75.10	75.06	75.11	75.07	75.08	75.08	03:00/01
06	75.17	75.16	75.15	75.16	75.10	75.17	75.12	75.16	75.12	75.10	75.06	75.07	75.16	75.07	75.08	75.259
07	75.16	75.16	75.17	75.14	75.12	75.13	75.14	75.14	75.13	75.10	75.07	75.06	75.14	75.07	75.07	
08	75.16	75.16	75.14	75.15	75.15	75.12	75.14	75.16	75.13	75.10	75.06	75.08	75.11	75.05	75.07	
09	75.15	75.15	75.11	75.14	75.12	75.20	75.15	75.17	75.13	75.11	75.06	75.06	75.10	75.08	75.07	Monthly
10	75.16	75.15	75.11	75.14	75.11	75.18	75.10	75.15	75.13	75.12	75.08	75.07	75.11	75.07	75.06	Min LWL
11	75.16	75.16	75.13	75.14	75.11	75.16	75.11	75.16	75.12	75.11	75.08	75.06	75.11	75.06	75.07	04:00/29
12	75.16	75.17	75.16	75.14	75.12	75.12	75.13	75.14	75.11	75.11	75.09	75.07	75.12	75.10	75.07	75.021
13	75.16	75.15	75.14	75.14	75.12	75.14	75.13	75.14	75.11	75.10	75.07	75.05	75.08	75.08	75.07	
14	75.16	75.17	75.13	75.15	75.10	75.11	75.14	75.14	75.10	75.11	75.06	75.08	75.08	75.08	75.06	
15	75.17	75.16	75.13	75.13	75.12	75.12	75.12	75.13	75.11	75.09	75.07	75.06	75.07	75.08	75.05	Monthly
16	75.16	75.16	75.13	75.13	75.13	75.14	75.14	75.13	75.12	75.09	75.08	75.05	75.09	75.05	75.06	Mean
17	75.18	75.16	75.13	75.13	75.08	75.11	75.16	75.13	75.10	75.07	75.08	75.07	75.08	75.09	75.06	MSL
18	75.17	75.15	75.14	75.16	75.12	75.13	75.13	75.13	75.10	75.07	75.08	75.06	75.08	75.09	75.06	75.152
19	75.16	75.16	75.13	75.14	75.11	75.11	75.10	75.14	75.10	75.08	75.06	75.05	75.07	75.09	75.06	
20	75.17	75.16	75.16	75.15	75.12	75.13	75.16	75.14	75.11	75.09	75.06	75.07	75.09	75.07	75.06	
21	75.18	75.14	75.11	75.13	75.16	75.12	75.17	75.14	75.11	75.08	75.07	75.05	75.09	75.07	75.04	
22	75.18	75.15	75.14	75.13	75.10	75.15	75.17	75.14	75.11	75.08	75.07	75.06	75.09	75.08	75.06	
23	75.18	75.14	75.14	75.12	75.09	75.14	75.18	75.14	75.11	75.08	75.09	75.05	75.10	75.08	75.05	
24	75.19	75.14	75.11	75.11	75.09	75.12	75.17	75.15	75.11	75.09	75.10	75.08	75.09	75.09	75.06	
Mean	75.17	75.16	75.14	75.14	75.12	75.14	75.14	75.15	75.12	75.10	75.07	75.07	75.09	75.08	75.07	

[] denotes inferred water level values Data Status: Verified

Figure 1.5. Hourly Height Water Level Data for a Great Lakes Station

1.4 Computation of Tidal Datums and Water Level Datums

1.4.1 National Tidal Datum Epoch

Tidal datums shall be computed relative to a specific 19 year tidal cycle adopted by the NOS called the National Tidal Datum Epoch (NTDE). The present NTDE is the period 1983 through 2001. A primary datum determination is based directly on the average of tide observations over the 19 year Epoch period at NOS permanent long term primary control stations in the National Water Level Observation Network (NWLON). The data from NOS primary stations are used to compute datums at short term subordinate stations by reducing the data from those subordinate stations to equivalent 19 year mean values through the method of comparison of simultaneous observation.

1.4.2 Computational Procedures

The equivalent 19 year tidal datums for subordinate stations are computed for certain phases of the tide using tide-by-tide comparisons or monthly mean comparisons with an appropriate NOS long term control station. Accepted 19 year mean values of mean tide level (MTL), mean range (MN), diurnal high water inequality (DHQ), diurnal low water inequality (DLQ), diurnal tide level (DTL), and great diurnal range (GT) are required in the reduction process in which a “short series” of tide observations at any location are compared with simultaneous observations from an NOS control station. Datums are computed by the “standard” method of range ratio comparison generally on the West coast and Pacific Islands where there exists a large diurnal inequality in the low and high waters. The “modified” method of range ratio comparison is generally used on the East coast and Caribbean where small differences exist in the low and high water diurnal inequalities. For stations requiring a datum determination, at least 30 continuous days of tide observations are required for stations where adequate primary datum control exists. For error budget purposes, one month of data results in a datum accuracy of 0.11 m (95% confidence level) for Stations in the Gulf of Mexico and 0.08 m (95% confidence level) for east and West Coast stations. Examples of a tide by tide and a monthly mean simultaneous comparison for datum determination are found in Figures 1.6 and 1.7.

Descriptions of the tidal datum computational procedures are found in the *Tide and Current Glossary* (<http://tidesandcurrents.noaa.gov/publications/glossary2.pdf>), *Tidal Datum Planes, Manual of Tide Observations, NOAA Special Publication NOS CO-OPS 1 Tidal Datums and Their Applications* (http://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf) and *Computational Techniques for Tidal Datums Handbook* (http://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf).

1.4.3 Tidal Datum Recovery

Whenever tide stations are installed at historical sites, measures shall be taken to “recover” the established tidal datums through leveling which shall be accomplished by referencing the gauge or tide staff zero (“0”) to more than one existing bench mark (three bench marks are required)

with a published tidal elevation. Through this process, the published MLLW elevation is transferred by level differences to the “new” gauge or tide staff and compared to the MLLW elevation computed from the new data on the same zero (“0”). Factors affecting the datum recovery (i.e. differences between old and newly computed datums) include the length of each data series used to compute the datums, the geographical location, the tidal characteristics in the region, the length of time between reoccupations, the sea level trends in the region, land level trends, and the control station used. Based on all of these factors, the datum recovery can be expected to vary from +/- 0.03 m to +/- 0.08 m. Thus successful datum recovery is defined as the difference of 8 cm or less between the old and newly computed datums. After a successful datum recovery is performed and benchmark stability is established, the historical value of Mean Lower Low Water (MLLW) and Mean High Water (MHW) shall be used as the operational datum reference for data from the gauge during shoreline mapping survey operations. Hence, this process also serves as a very useful quality control procedure. In case of unsuccessful datum recovery, CO-OPS will evaluate all the factors and determine whether the data is acceptable or not. An example of a published tidal datum sheet for a station for which a datum recovery could be made is found in [Figure 1.8](#).

1.4.4 Datum Quality Control

It is essential for tidal datum quality control to have data processing and leveling procedures carried out as specified. Caution must also be used in computing tidal datums in rivers, tributaries, or in regions of unknown tidal regimes. Tide-by-tide comparisons between subordinate and control station data will often detect anomalous differences which should be investigated for possible gauge malfunction or sensor movement. Differences in elevations between bench marks based on new leveling must agree with previously established differences from the published bench mark sheets unless marks are destroyed or marks are disturbed by earthquakes, hurricanes, etc. Any changes in the elevation differences must be reconciled before using in any datum recovery procedure. Datum accuracy at a subordinate station depends on various factors, but availability and choice of an adequate control station of similar tidal characteristics, similar daily mean sea level and seasonal mean sea level variations, and similar sea level trends are the most important. The length of series will also determine accuracy. The longer the series, the more accurate the datum and the greater quality control and confidence gained from analyzing numerous monthly mean differences between the subordinate and control station. At reoccupied historical stations for which datum recoveries are made, updated datums shall be computed from the new time series and compared with the historical datums as the survey progresses.

Begin: Jun 15 2005 00:00
 End: Jul 14 2005 23:54
 Run: Jan 31 2007 16:30

COMPARISON OF SIMULTANEOUS OBSERVATIONS

Tidal Epoch: 1983-2001
 Expected Diff: 0.55 Hrs
 * Exceeds 2 Standard Dev

(A) Subordinate Station: 9414863 RICHMOND, CHEVRON OIL PIER
 (B) Standard Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY
 Verified T.M.: OW Tide Type: Mixed
 Verified T.M.: OW Tide Type: Mixed

(A) STATION Time of				(B) STATION Time of				(A) - (B) Time Difference		(A) STATION Height of		(B) STATION Height of		(A) - (B) Height Difference		
2005	HW Hour	Date	LW Hour	Date	HW Hour	Date	LW Hour	HW Hours	LW Hours	HW Meters	LW Meters	HW Meters	LW Meters	HW Meters	LW Meters	
Jun 15	2.3	HH	Jun 15 8.4	L	Jun 15 2.0	HH	Jun 15 7.5	L	0.3	0.9	5.091	4.266	3.304	2.546	1.787	1.720
Jun 15	13.6	H	Jun 15 19.7	LL	Jun 15 13.2	H	Jun 15 19.0	LL	0.4	0.7	4.745	3.890	2.970	2.222	1.775	1.668*
Jun 16	3.0	HH	Jun 16 9.3	L	Jun 16 2.5	HH	Jun 16 8.4	L	0.5	0.9	5.193	4.065	3.412	2.362	1.781	1.703
Jun 16	15.0	H	Jun 16 20.5	L	Jun 16 14.6	H	Jun 16 19.7	L	0.4	0.8	4.731	4.070	2.953	2.350	1.778	1.720
Jun 17	3.4	HH	Jun 17 10.0	LL	Jun 17 3.0	HH	Jun 17 9.1	LL	0.4	0.9	5.347	3.861	3.566	2.144	1.781	1.717
Jun 17	16.1	H	Jun 17 21.4	L	Jun 17 15.7	H	Jun 17 20.6	L	0.4	0.8	4.736	4.140	2.960	2.418	1.776	1.722
Jun 18	4.0	HH	Jun 18 10.8	LL	Jun 18 3.5	HH	Jun 18 10.1	LL	0.5	0.7	5.400	3.657	3.612	1.919	1.788	1.738
Jun 18	17.4	H	Jun 18 22.2	L	Jun 18 17.0	H	Jun 18 21.6	L	0.4	0.6	4.793	4.265	3.015	2.539	1.778	1.726
Jun 19	4.5	HH	Jun 19 11.8	LL	Jun 19 4.1	HH	Jun 19 11.1	LL	0.4	0.7	5.528	3.440	3.728	1.714	1.800	1.726
Jun 19	18.6	H	Jun 19 23.0	L	Jun 19 18.1	H	Jun 19 22.4	L	0.5	0.6	4.833	4.365	3.057	2.626	1.776	1.739
Jun 20	5.2	HH	Jun 20 12.6	LL	Jun 20 5.0	HH	Jun 20 11.9	LL	0.2*	0.7	5.603	3.249	3.806	1.503	1.797	1.746
Jun 20	19.5	H	Jun 20 23.8	L	Jun 20 19.1	H	Jun 20 23.2	L	0.4	0.6	4.893	4.452	3.107	2.722	1.786	1.730
Jun 21	5.8	HH	Jun 21 13.4	LL	Jun 21 5.5	HH	Jun 21 12.9	LL	0.3	0.5	5.681	3.127	3.887	1.368	1.794	1.759
Jun 21	20.4	H	Jun 22 0.6	L	Jun 21 20.1	H	Jun 22 0.1	L	0.3	0.5	4.961	4.482	3.167	2.753	1.794	1.729
Jun 22	6.5	HH	Jun 22 14.2	LL	Jun 22 6.2	HH	Jun 22 13.6	LL	0.3	0.6	5.727	3.026	3.933	1.248	1.794	1.778
Jun 22	21.3	H	Jun 23 1.6	L	Jun 22 20.9	H	Jun 23 1.0	L	0.4	0.6	4.984	4.498	3.192	2.766	1.792	1.732
Jun 23	7.6	HH	Jun 23 15.0	LL	Jun 23 7.2	HH	Jun 23 14.4	LL	0.4	0.6	5.736	2.999	3.936	1.230	1.800	1.769
Jun 23	22.1	H	Jun 24 2.5	L	Jun 23 21.7	H	Jun 24 1.9	L	0.4	0.6	5.024	4.476	3.230	2.755	1.794	1.721
Jun 24	8.2	HH	Jun 24 15.9	LL	Jun 24 7.8	HH	Jun 24 15.1	LL	0.4	0.8	5.711	3.054	3.935	1.307	1.776	1.747
Jun 24	22.9	H	Jun 25 3.5	L	Jun 24 22.3	H	Jun 25 2.9	L	0.6	0.6	5.084	4.436	3.309	2.714	1.775	1.722
Jun 25	9.2	HH	Jun 25 16.6	LL	Jun 25 8.8	HH	Jun 25 15.7	LL	0.4	0.9	5.615	3.164	3.839	1.415	1.776	1.749
Jun 25	23.7	H	Jun 26 4.5	L	Jun 25 23.1	H	Jun 26 4.0	L	0.6	0.5	5.165	4.387	3.394	2.678	1.771	1.709
Jun 26	10.3	HH	Jun 26 17.5	LL	Jun 26 9.9	HH	Jun 26 16.6	LL	0.4	0.9	5.453	3.316	3.674	1.577	1.779	1.739
Jun 27	0.4	H	Jun 27 5.7	L	Jun 26 23.7	HH	Jun 27 5.1	L	0.7*	0.6	5.243	4.299	3.477	2.579	1.766*	1.720
Jun 27	11.4	HH	Jun 27 18.1	LL	Jun 27 10.8	H	Jun 27 17.3	LL	0.6	0.8	5.257	3.478	3.467	1.744	1.790	1.734
Jun 28	1.2	HH	Jun 28 6.9	L	Jun 28 0.6	HH	Jun 28 6.4	L	0.6	0.5	5.313	4.167	3.538	2.451	1.775	1.716
Jun 28	12.6	H	Jun 28 18.7	LL	Jun 28 12.1	H	Jun 28 18.1	LL	0.5	0.6	5.007	3.639	3.217	1.921	1.790	1.718
Jun 29	1.9	HH	Jun 29 8.2	L	Jun 29 1.4	HH	Jun 29 7.5	L	0.5	0.7	5.381	3.997	3.591	2.274	1.790	1.723
Jun 29	14.0	H	Jun 29 19.5	LL	Jun 29 13.6	H	Jun 29 18.9	LL	0.4	0.6	4.883	3.908	3.094	2.210	1.789	1.698
Jun 30	2.6	HH	Jun 30 9.3	LL	Jun 30 2.1	HH	Jun 30 8.7	LL	0.5	0.6	5.486	3.850	3.711	2.119	1.775	1.731
Jun 30	15.6	H	Jun 30 20.6	L	Jun 30 15.2	H	Jun 30 20.1	L	0.4	0.5	4.824	4.151	3.047	2.445	1.777	1.706
Jul 1	3.3	HH	Jul 1 10.3	LL	Jul 1 2.9	HH	Jul 1 9.8	LL	0.4	0.5	5.521	3.694	3.741	1.957	1.780	1.737
Jul 1	17.1	H	Jul 1 21.8	L	Jul 1 16.7	H	Jul 1 21.2	L	0.4	0.6	4.867	4.347	3.083	2.625	1.784	1.722
Jul 2	4.2	HH	Jul 2 11.3	LL	Jul 2 3.7	HH	Jul 2 10.7	LL	0.5	0.6	5.554	3.565	3.768	1.816	1.786	1.749
Jul 2	18.4	H	Jul 2 22.7	L	Jul 2 17.9	H	Jul 2 22.2	L	0.5	0.5	4.943	4.500	3.152	2.770	1.791	1.730
Jul 3	4.7	HH	Jul 3 12.2	LL	Jul 3 4.3	HH	Jul 3 11.5	LL	0.4	0.7	5.590	3.464	3.809	1.712	1.781	1.752
Jul 3	19.4	H	Jul 3 23.5	L	Jul 3 18.9	H	Jul 3 23.1	L	0.5	0.4	4.963	4.519	3.180	2.797	1.783	1.722
Jul 4	5.6	HH	Jul 4 12.9	LL	Jul 4 5.1	HH	Jul 4 12.2	LL	0.5	0.7	5.571	3.379	3.782	1.637	1.789	1.742
Jul 4	20.1	H	Jul 5 0.4	L	Jul 4 19.6	H	Jul 4 23.9	L	0.5	0.5	5.016	4.579	3.230	2.853	1.786	1.726
Jul 5	6.0	HH	Jul 5 13.5	LL	Jul 5 5.5	HH	Jul 5 12.7	LL	0.5	0.8	5.540	3.354	3.751	1.598	1.789	1.756
Jul 5	20.9	H	Jul 6 1.2	L	Jul 5 20.3	H	Jul 6 0.6	L	0.6	0.6	5.029	4.598	3.244	2.861	1.785	1.737
Jul 6	6.9	HH	Jul 6 14.1	LL	Jul 6 6.3	HH	Jul 6 13.5	LL	0.6	0.6	5.521	3.354	3.734	1.601	1.787	1.753
Jul 6	21.5	H	Jul 7 1.9	L	Jul 6 20.9	H	Jul 7 1.3	L	0.6	0.6	5.056	4.584	3.272	2.860	1.784	1.724

Figure 1.6. Tide-By-Tide Comparison

Begin: Jun 15 2005 00:00
 End: Jul 14 2005 00:00
 Run: Jan 31 2007 16:30

COMPARISON OF SIMULTANEOUS OBSERVATIONS

Tidal Epoch: 1983-2001
 Expected Diff: 0.55 Hrs
 * Exceeds 2 Standard Dev

(A) Subordinate Station: 9414863 RICHMOND, CHEVRON OIL PIER
 (B) Standard Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY
 Verified T.M.: OW Tide Type: Mixed
 Verified T.M.: OW Tide Type: Mixed

(A) STATION Time of				(B) STATION Time of				(A) - (B) Time Difference		(A) STATION Height of		(B) STATION Height of		(A) - (B) Height Difference			
2005	HW Hour	Date	LW Hour	Date	HW Hour	Date	LW Hour	HW Hours	LW Hours	Meters	Meters	Meters	Meters	Meters	Meters		
Jul 7	7.4 HH	Jul 7	14.8 LL	Jul 7	7.2 HH	Jul 7	13.9 LL	0.2*	0.9	5.510	3.380	3.715	1.622	1.795	1.758		
Jul 7	22.0 H	Jul 8	2.4 L	Jul 7	21.4 H	Jul 8	1.9 L	0.6	0.5	5.037	4.533	3.248	2.822	1.789	1.711		
Jul 8	8.0 HH	Jul 8	15.3 LL	Jul 8	7.6 HH	Jul 8	14.5 LL	0.4	0.8	5.444	3.397	3.660	1.654	1.784	1.743		
Jul 8	22.5 H	Jul 9	3.0 L	Jul 8	21.9 H	Jul 9	2.4 L	0.6	0.6	5.016	4.478	3.225	2.775	1.791	1.703		
Jul 9	8.7 HH	Jul 9	15.8 LL	Jul 9	8.2 HH	Jul 9	15.1 LL	0.5	0.7	5.375	3.453	3.587	1.719	1.788	1.734		
Jul 9	23.1 H	Jul 10	3.7 L	Jul 9	22.5 H	Jul 10	3.2 L	0.6	0.5	5.036	4.462	3.245	2.760	1.791	1.702		
Jul 10	9.5 HH	Jul 10	16.2 LL	Jul 10	8.9 HH	Jul 10	15.5 LL	0.6	0.7	5.267	3.541	3.476	1.802	1.791	1.739		
Jul 10	23.6 H	Jul 11	4.5 L	Jul 10	23.1 H	Jul 11	4.0 L	0.5	0.5	5.059	4.432	3.260	2.728	1.799	1.704		
Jul 11	9.9 HH	Jul 11	16.8 LL	Jul 11	9.5 HH	Jul 11	16.0 LL	0.4	0.8	5.153	3.622	3.365	1.900	1.788	1.722		
Jul 12	0.1 H	Jul 12	5.5 L	Jul 11	23.7 H	Jul 12	4.9 L	0.4	0.6	5.110	4.359	3.325	2.651	1.785	1.708		
Jul 12	10.8 H	Jul 12	17.2 LL	Jul 12	10.4 H	Jul 12	16.5 LL	0.4	0.7	4.992	3.705	3.211	1.998	1.781	1.707		
Jul 13	0.6 HH	Jul 13	6.3 L	Jul 13	0.1 HH	Jul 13	5.8 L	0.5	0.5	5.155	4.294	3.362	2.565	1.793	1.729		
Jul 13	11.7 H	Jul 13	17.8 LL	Jul 13	11.3 H	Jul 13	17.1 LL	0.4	0.7	4.875	3.899	3.090	2.204	1.785	1.695		
										HHW	HLW	HHW	HLW	HHW	HLW		
SUMS										152.709	122.201	102.699	74.045	50.010	48.156		
ITEMS										28	28	28	28	28	28		
MEANS										5.454	4.364	3.668	2.644	1.786	1.720		
STD DEV														0.007	0.011		
										LHW	LLW	LHW	LLW	LHW	LLW		
SUMS										25.60	36.50	138.919	97.465	88.944	48.861	49.975	48.604
ITEMS										56	56	28	28	28	28	28	28
MEANS										0.46	0.65	4.961	3.481	3.177	1.745	1.785	1.736
STD DEV										0.11	0.13					0.008	0.024

Figure 1.6. Tide-By-Tide Comparison (continued)

Begin: Jun 15 2005 00:00
 End: Jul 14 2005 00:00
 Run: Jan 31 2007 16:30

COMPARISON OF SIMULTANEOUS OBSERVATIONS

Tidal Epoch: 1983-2001
 Expected Diff: 0.55 Hrs
 * Exceeds 2 Standard Dev

(A) Subordinate Station: 9414863 RICHMOND, CHEVRON OIL PIER
 (B) Standard Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY

Mean Difference in HWI: 0.46
 Mean HHW Height at (A): 5.454
 Mean LHW Height at (A): 4.961
 DHQ at (A): 0.246
 Mean HW Height at (A): 5.208
 MN at (A): 1.285
 GT at (A): 1.973

Mean Difference in LWI: 0.65
 Mean HLW Height at (A): 4.364
 Mean LLW Height at (A): 3.481
 DLQ at (A): 0.442
 Mean LW Height at (A): 3.923
 MTL at (A): 4.565
 DTL at (A): 4.467

Mean HHW Difference: 1.786
 Mean LHW Difference: 1.785
 DHQ Difference: 0.001
 Mean HW Difference: 1.785
 MN Difference: 0.058
 GT Difference: 0.050
 MN Ratio: 1.047
 GT Ratio: 1.026
 MSL (100.00%) at (A): 4.548
 MSL (100.00%) at (B): 2.782
 MSL Difference: 1.766

Mean HLW Difference: 1.720
 Mean LLW Difference: 1.736
 DLQ Difference: -0.008
 Mean LW Difference: 1.728
 MTL Difference: 1.757
 DTL Difference: 1.761
 DHQ Ratio: 1.003
 DLQ Ratio: 0.982

	HWI	LWI	MTL	MN	MSL	DHQ	DLQ
	Hours	Hours	Meters	Meters	Meters	Meters	Meters
Accepted for B:	7.53	0.85	2.792	1.248	2.773	0.186	0.346
Differences and Ratios:	0.46	0.65	1.757	1.047	1.766	1.003	0.982
Corrected for A:	7.99	1.50	4.549	1.307	4.539	0.186	0.340

FINAL/PRELIMINARY DATUMS Standard Method

MHHW	---	---	5.388				
MHW	-	-	5.202	DHQ	0.186		
DTL	-	-	4.472			GT	1.833
MTL	-	-	4.549			MN	1.307
MSL	-	-	4.539				
MLW	-	-	3.895				
MLLW	---	---	3.555	DLQ	0.340		
On Staff Of:						HWI:	7.99
						LWI:	1.50

Date _____ ID _____
 Comparison _____
 Verified _____

Figure 1.6. Tide-By-Tide Comparison (concluded)

COMPARISON OF MONTHLY MEANS (Jan 2005 - Dec 2005)
 1983-2001 TIDAL EPOCH

Feb 01, 2007

		(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER						Product		TM (OW)		TIDE TYPE (M)				
		(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY						Product		TM (OW)		TIDE TYPE (M)				
Mon	Year	A	M T L	A - B	A	M S L	A - B	A	H W I	A - B	A	L W I	A - B	A	M N	A / B
		METER	METER	METER	METER	METER	METER	HRS	HRS	HRS	HRS	HRS	HRS	METER	METER	RATIO
Jan	2005	4.665	2.900	1.765	4.650	2.876	1.774	7.890	7.450	0.440	1.380	0.750	0.630	1.293	1.212	1.067
Feb	2005	4.639	2.875	1.764	4.626	2.853	1.773	7.970	7.520	0.450	1.430	0.800	0.630	1.315	1.239	1.061
Mar	2005	4.593	2.813	1.780	4.575	2.791	1.784	7.890	7.450	0.440	1.320	0.690	0.630	1.288	1.207	1.067
Apr	2005	4.503	2.740	1.763	4.485	2.713	1.772	7.890	7.500	0.390	1.380	0.720	0.660	1.276	1.199	1.064
May	2005	4.563	2.805	1.758	4.542	2.773	1.769	7.890	7.480	0.410	1.430	0.720	0.710	1.281	1.209	1.060
Jun	2005	4.535	2.780	1.755	4.517	2.750	1.767	7.870	7.450	0.420	1.430	0.710	0.720	1.274	1.210	1.053
Jul	2005	4.607	2.856	1.751	4.590	2.826	1.764	7.950	7.490	0.460	1.460	0.840	0.620	1.284	1.231	1.043
Aug	2005	4.604	2.864	1.740	4.593	2.838	1.755	7.970	7.520	0.450	1.490	0.880	0.610	1.279	1.230	1.040
Sep	2005	4.571	2.838	1.733	4.565	2.819	1.746	7.880	7.460	0.420	1.420	0.830	0.590	1.273	1.225	1.039
Oct	2005		2.809			2.787			7.420			0.810			1.235	
Nov	2005		2.781			2.751			7.440			0.830			1.229	
Dec	2005		2.840			2.805			7.460			0.800			1.245	

Mon	Year	A	D H Q	A / B	A	D L Q	A / B	A	M H W	A - B	A	M L W	A - B
		METER	METER	RATIO	METER	METER	RATIO	METER	METER	METER	METER	METER	METER
Jan	2005	0.227	0.224	1.013	0.401	0.406	0.988	5.312	3.506	1.806	4.019	2.294	1.725
Feb	2005	0.207	0.204	1.015	0.350	0.354	0.989	5.296	3.494	1.802	3.981	2.255	1.726
Mar	2005	0.154	0.152	1.013	0.329	0.324	1.015	5.237	3.417	1.820	3.949	2.210	1.739
Apr	2005	0.156	0.156	1.000	0.388	0.380	1.021	5.141	3.339	1.802	3.865	2.140	1.725
May	2005	0.179	0.179	1.000	0.431	0.427	1.009	5.204	3.409	1.795	3.923	2.200	1.723
Jun	2005	0.246	0.245	1.004	0.439	0.439	1.000	5.172	3.385	1.787	3.898	2.175	1.723
Jul	2005	0.258	0.257	1.004	0.429	0.441	0.973	5.249	3.471	1.778	3.965	2.240	1.725
Aug	2005	0.218	0.216	1.009	0.376	0.393	0.957	5.244	3.479	1.765	3.965	2.249	1.716
Sep	2005	0.161	0.156	1.032	0.305	0.324	0.941	5.207	3.451	1.756	3.934	2.226	1.708
Oct	2005		0.140			0.324			3.427			2.192	
Nov	2005		0.204			0.417			3.395			2.166	
Dec	2005		0.256			0.487			3.462			2.217	

Mon	Year	A	D R L(TL)	A - B	A	G T	A / B	A	M H H W	A - B	A	M L L W	A - B
		METER	METER	RATIO	METER	METER	RATIO	METER	METER	METER	METER	METER	METER
Jan	2005	4.579	2.809	1.770	1.921	1.842	1.043	5.539	3.730	1.809	3.618	1.888	1.730
Feb	2005	4.567	2.800	1.767	1.872	1.797	1.042	5.503	3.698	1.805	3.631	1.901	1.730
Mar	2005	4.505	2.728	1.777	1.771	1.683	1.052	5.391	3.569	1.822	3.620	1.886	1.734
Apr	2005	4.387	2.628	1.759	1.820	1.735	1.049	5.297	3.495	1.802	3.477	1.760	1.717
May	2005	4.438	2.680	1.758	1.891	1.815	1.042	5.383	3.588	1.795	3.492	1.773	1.719
Jun	2005	4.439	2.683	1.756	1.959	1.894	1.034	5.418	3.630	1.788	3.459	1.736	1.723
Jul	2005	4.521	2.764	1.757	1.971	1.929	1.022	5.507	3.728	1.779	3.536	1.799	1.737
Aug	2005	4.526	2.776	1.750	1.873	1.839	1.018	5.462	3.695	1.767	3.589	1.856	1.733
Sep	2005	4.498	2.755	1.743	1.739	1.705	1.020	5.368	3.607	1.761	3.629	1.902	1.727
Oct	2005		2.718			1.699			3.567			1.868	
Nov	2005		2.674			1.850			3.599			1.749	
Dec	2005		2.724			1.988			3.718			1.730	

Figure 1.7. Monthly Mean Simultaneous Comparison Example

COMPARISON OF MONTHLY MEANS (Jan 2005 - Dec 2005)
 1983-2001 TIDAL EPOCH

Feb 01, 2007

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER Product TM (OW) TIDE TYPE (M)
 (B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY Product TM (OW) TIDE TYPE (M)

O U T L I E R R E P O R T

(MEAN DIFFERENCE EXCEEDS 2 STD. DEV. (MAX/MIN))

Std. Dev.	M T L	M S L	H W I	L W I	M N	D H Q	D L Q	M H W	M L W	D T L	G T	M H H W	M L L W	Std. Dev.
0.009	0.007	0.014	0.034	0.007	0.008	0.016	0.013	0.005	0.007	0.008	0.013	0.004	0.004	MAX
1.774	1.780	0.459	0.712	1.069	1.025	1.021	1.816	1.734	1.774	1.052	1.818	1.736	1.736	MIN
1.739	1.754	0.404	0.577	1.041	0.995	0.956	1.765	1.713	1.745	1.020	1.766	1.719	1.719	
MON YEAR														
Jan 2005														Jan 2005
Feb 2005														Feb 2005
Mar 2005	1.780	1.784						1.820	1.739	1.777	1.052	1.822		Mar 2005
Apr 2005			0.390				1.021						1.717	Apr 2005
May 2005													1.719	May 2005
Jun 2005				0.720										Jun 2005
Jul 2005			0.460										1.737	Jul 2005
Aug 2005					1.040					1.018				Aug 2005
Sep 2005	1.733	1.746			1.039	1.032	0.941	1.756	1.708	1.743		1.761		Sep 2005
Oct 2005														Oct 2005
Nov 2005														Nov 2005
Dec 2005														Dec 2005

Figure 1.7. Monthly Mean Simultaneous Comparison (concluded)

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National Ocean Service

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

To reach the tidal bench marks, proceed west along U.S. Highway 101 in the direction of the Golden Gate Bridge, then NW along Crissey Field Avenue (before the bridge) to the Golden Gate National Park (Presidio). The bench marks are located mostly along the coast in the vicinity. The tide gauge is located on the NE side of the National Parks Service wharf.

T I D A L B E N C H M A R K S

PRIMARY BENCH MARK STAMPING: 180 1936
DESIGNATION: 941 4290 TIDAL 180

MONUMENTATION: Tidal Station disk VM#: 967
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0702
SETTING CLASSIFICATION: Concrete sea wall

The primary bench mark is a disk set in the top of a 1 m (3 ft) high concrete seawall in Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, 15 m (50 ft) east of the NE corner of the Sanctuaries building, 6.10 m (20.0 ft) south of the south side of the garage building, and 1.07 m (3.5 ft) north of an angle in wall.

BENCH MARK STAMPING: BM 174 1925
DESIGNATION: 941 4290 TIDAL 174
ALIAS: TIDAL 174

MONUMENTATION: Tidal Station disk VM#: 971
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0697
SETTING CLASSIFICATION: Concrete monument

The bench mark is a disk set in a concrete post flush with the ground inside a circle of bricks in the pavement, 38.10 m (125.0 ft) west of the extended west edge of Engineer's Dock where it crosses Marine Drive, at the center of "Y" between Marine Drive and the road leading SE to Fort Winfield Scott, 12.95 m (42.5 ft) SW of the fire hydrant, and 8.69 m (28.5 ft) south of the south edge of an iron manhole cover.

Figure 1.8. Published Bench Mark Sheet

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: BM 176 1925
DESIGNATION: 941 4290 TIDAL 176
ALIAS: TIDAL 176

MONUMENTATION: Tidal Station disk VM#: 972
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0705
SETTING CLASSIFICATION: Concrete step

The bench mark is a disk set in the west end of the lowest concrete step at the main entrance to the porch of the building at No. 651 Mason Street, 29.87 m (98.0 ft) SE of the intersection of Crissey Field Avenue and Mason Street, 15.24 m (50.0 ft) south of the centerline of Mason Street, and 0.21 m (0.7 ft) above sidewalk.

BENCH MARK STAMPING: 181 1945
DESIGNATION: 941 4290 TIDAL 181
ALIAS: TIDAL 181

MONUMENTATION: Tidal Station disk VM#: 973
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0701
SETTING CLASSIFICATION: Sea wall

The bench mark is a disk set in NW corner of a sea wall at the Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, 62 m (204 ft) west of the inshore end of the pier, 45.87 m (150.5 ft) NW of a flag pole, 21.64 m (71.0 ft) NE of the north corner of Building S.F. 19.4 (paint shop and storage building), and 1.22 m (4.0 ft) above ground.

Figure 1.8 Published Bench Mark Sheet (continued)

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: NO 2 1948
DESIGNATION: CLARK RM 2
ALIAS: 941 4290 TIDAL 183

MONUMENTATION: Triangulation Station disk VM#: 975
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0700
SETTING CLASSIFICATION: Sea wall

The bench mark is a disk set flush in the top of a sea wall west of the public fishing pier, 11.43 m (37.5 ft) west of the west edge of the pier, 8.08 m (26.5 ft) NE of the NE corner of corrugated iron building No. 985, and about 0.91 m (3.0 ft) above ground.

BENCH MARK STAMPING: CLARK 1948
DESIGNATION: CLARK
ALIAS: 941 4290 TIDAL 185

MONUMENTATION: Triangulation Station disk VM#: 976
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0698
SETTING CLASSIFICATION: Concrete sea wall

The bench mark is a disk set in the top of a concrete sea wall west of the public fishing pier, about 549 m (1800 ft) NW of the Gulf of Farallons National Marine Sanctuary headquarters in Golden Gate National Park, 24.23 m (79.5 ft) west of the west edge of the pier, 6.86 m (22.5 ft) NE of the NW corner of corrugated iron building No. 985, 3.05 m (10.0 ft) west of the NW corner of a stucco paint locker building, and 1.07 m (3.5 ft) above ground.

Figure 1.8: Published Bench Mark Sheet (continued)

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 4290 K 1976
DESIGNATION: 941 4290 K TIDAL

MONUMENTATION: Tidal Station disk VM#: 978
AGENCY: National Ocean Service (NOS) PID: HT2255
SETTING CLASSIFICATION: Bedrock

The bench mark is a disk set vertically in bedrock on the south side of Marine Drive, 24 m (79 ft) SSW of the SE corner of the National Park Service building # T989, 14.69 m (48.2 ft) NW of bench mark BM 174 1925, and 2.44 m (8.0 ft) south of the road curb.

BENCH MARK STAMPING: 4290 L 1976
DESIGNATION: 941 4290 L TIDAL

MONUMENTATION: Tidal Station disk VM#: 979
AGENCY: National Ocean Survey (NOS) PID: HT2253
SETTING CLASSIFICATION: Bedrock

The bench mark is a disk set in bedrock on the south side of Marine Drive, 114 m (375 ft) west of the National Park Service building # T989, 15.70 m (51.5 ft) SE of the eastern-most concrete and steel safety chain stanchion on the seawall, 7.77 m (25.5 ft) from the centerline of Marine Drive, and 1.22 m (4 ft) above street level.

Figure 1.8: Published Bench Mark Sheet (continued)

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 4290 N 1995
DESIGNATION: 941 4290 N

MONUMENTATION: Tidal Station disk VM#: 15436
AGENCY: National Ocean Service (NOS) PID: AE5209
SETTING CLASSIFICATION: Concrete sea wall

The bench mark is a disk set in a concrete seawall in Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, near an inshore end of a walkway leading to a pier, 13.70 m (44.9 ft) north of bottom of stairs leading to the Sanctuary building, 3.96 m (13.0 ft) east of a step in seawall, and 3.20 m (10.5 ft) west of the center of the walkway.

Figure 1.8: Published Bench Mark Sheet (continued)

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L D A T U M S

Tidal datums at SAN FRANCISCO based on:

LENGTH OF SERIES: 19 Years
TIME PERIOD: January 1983 - December 2001
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION:

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (01/27/1983) = 2.640
MEAN HIGHER HIGH WATER (MHHW) = 1.780
MEAN HIGH WATER (MHW) = 1.595
MEAN TIDE LEVEL (MTL) = 0.970
MEAN SEA LEVEL (MSL) = 0.951
MEAN LOW WATER (MLW) = 0.346
MEAN LOWER LOW WATER (MLLW) = 0.000
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) = -0.018
LOWEST OBSERVED WATER LEVEL (12/17/1933) = -0.877

Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
180 1936	3.972	2.378
BM 174 1925	5.013	3.418
BM 176 1925	4.814	3.219
181 1945	3.987	2.392
NO 2 1948	4.221	2.626
CLARK 1948	4.233	2.639
4290 K 1976	5.828	4.234
4290 L 1976	6.620	5.025
4290 M 1982	3.705	2.111
BM 175 1925	4.160	2.566
4290 N 1995	3.646	2.051

Figure 1.8: Published Bench Mark Sheet (continued)

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National Ocean Service

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Station ID:	9414290	PUBLICATION DATE:	04/21/2003
Name:	SAN FRANCISCO CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at http://www.ngs.noaa.gov/cgi-bin/ngs_opsd.prl?PID=HT0702&EPOCH=1983-2001.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at http://www.ngs.noaa.gov/cgi-bin/ngs_opsd.prl?PID=HT0702&EPOCH=1983-2001.

NGVD 29 and NAVD 88 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.

Figure 1.8: Published Bench Mark Sheet (concluded)

1.5 Data Submission Requirements

Data submission requirements for water level measurement stations are comprised of timely submissions of both documentation and data, which involve (a) supporting documents for the installation, maintenance, and removal of stations, (b) the formatted digital water level data collected by the water level measurement system required for the quality control and ingestion into the CO-OPS data base management system, and (c) documentation for processing and tabulation of the data, and tidal datum computation are required.

Data submission requirements for GPS are listed as specified in CO-OPS “User’s Guide for GPS Observations At Tide and Water Level Station Bench Marks”.

(http://tidesandcurrents.noaa.gov/publications/Users_Guide_for_GPS_Observations_updated_November_2008.pdf)

1.5.1 Station Documentation

The documentation package shall be forwarded after (a) installation of a station, (b) performance of bracketing levels, (c) gauge maintenance and repair, or (d) removal of the station. Refer to Section 1.5.3 for required documentation details and time lines for submission requirements, and [Figure 1.9](#), Water Level Station Documentation Check-off List provides additional details.

For Each Water Level Station:

PROJECT DOCUMENTATION AND DATA CHECK-OFF LIST

Project Number: _____ **Locality:** _____

Station Number: _____ **Station Name:** _____

A. Transmittal Letter

	1. Transmittal letter attached with current contractor address, phone number and email.
--	---

B. Site Report (required for both installation and removal)

	1. All applicable information complete, especially serial numbers of DCP/sensors and dates of installation/removal of DCP/sensors and levels
	2. Verify latitude and longitude of the station (ensure that this is the same as on the field tide note for Hydro/Photo surveys). Provide latitude and longitude in d/m/s.x format as determined by handheld GPS for the primary sensor.
	3. Note UTC time and date the datum offset and sensor offset entered or changed in the DCP
	4. Provide metadata for ancillary sensors, if installed and as required
	5. Provide notes on results of diving inspection, and cleaning of underwater components.
	6. Provide status of valid tie to NAVD 88 geodetic marks, if applicable, in level section remarks area.
	7. Provide notes of excessive movement of water level sensor or bench marks in level section remarks area.

C. NOAA Chart Section

	1. Ensure that station location is clearly depicted with circle and station number.
	2. Standard title block includes station number, station name, lat/long as d/m/s.x., NOAA chart number, edition, date, and scale, USGS quad name all in caps.
	3. Provide a digital copy of the chart section in jpg format

D. Bench Mark/Station Location Sketch

	1. Ensure gauge, staff and bench marks are shown, and local body of water is labeled.
	2. Ensure Standard Title block includes: station number and station name, field unit, date of revision
	3. Ensure North arrow depicted.
	4. Include in digital format.
	5. Ensure all active (recovered and not recovered) bench marks are identified by designations
	6. Ensure bench marks that are confirmed as destroyed are removed from the sketch.

	7. Provide a digital copy of the sketch saved in jpg format.
--	--

E. Digital Photographs

	1. Provide digital photographs of gauge, staff, surrounding area, wells and brackets, DCP. Provide tide gauge photos from two perpendicular directions.
	2. Station component file name starts with station number followed by the specific component view, with jpg extension (e.g. 86610170 well.jpg)
	3. Provide several shots of met towers and sensors from different directions (e.g. 8661070 met tower looking east.jpg)
	4. Provide digital photos of bench mark – 4 photos required as follows - close up of disk without GPS handheld in view, eye-level view looking down, and two photos looking horizontally from different directions (90 degrees apart, if possible) showing general location for all new marks. Follow bench mark photo file naming convention as specified by NGS.

F. Bench Mark Descriptions/Recovery Notes

	1. Stampings for new and recovered marks verified in all documents.
	2. Descriptions for new marks provided in CO-OPS format (MS Word).
	3. Recovery notes provided for all historical marks. Recovered As Described (RAD) RAD/xxx noted for all recovered marks, where xxx is party chief, or contractor initial.
	4. Provide handheld GPS position in d/m/s.x format at the end of the text description.
	5. For electronic levels, make sure HA files codes are completed accurately
	6. For electronic levels, text description begins with a statement on how to reach the mark, followed by the description in CO-OPS format
	7. For electronic levels, provide handheld GPS position in d/m/s format at the end of the text in HA file since HA file does not accept decimal seconds s.x

G. Levels

	1. Ensure all information written in ink.
	2. Station name, number, level instrument type model and serial number, rods type model and serial numbers, date, personnel.
	3. Note type of levels - installation, bracketing and closing.
	4. Staff information complete (if applicable).
	5. Collimation check shown.
	6. Note that bench mark descriptions are submitted for all installed and recovered marks as a MS Word file.
	7. Headers on all applicable pages complete.
	8. For multi year projects, all marks must be connected every two years.
	9. Levels include marks specially noted in station specific requirements of the project instructions.
	10. Explanation provided for any marks not leveled during this level run.
	11. Provide sectional and overall closure tolerances and ascertain they are within allowable limits.
	12. Compute level abstract starting with PBM accepted elevation and ending with

	primary sensor elevation
	13. Check for valid leveling tie to NAVD 88 if required and made.
	14. For electronic levels, provide original IN file in separate folder if modified IN file is provided.
	15. For electronic levels, all file dates must be chronologically consistent, i.e. the HA and INX files can not have dates more recent than the ABS file
	16. For electronic levels, provide Invar rod calibration certificates for the first time digital leveling. For optical levels provide rod calibration certificates.
	17. For electronic levels, error flags are not allowed on sectional distances of the ABS file

H. Datum Offset Computation Worksheet

	1. Submit for stations that have Vitel or Sutron DCP with Aquatrak sensor.
--	--

I. Data Submitted in electronic media (CD-ROM/DVD/FTP site)

	1. Label electronic media with contractor name and list of files on each media.
	2. 6-minute Data files should be named in the following format: xxxxxxxy.w1.dat, where xxxxxxx = seven digit station number and y is the DCP # and w1 is the product code. For multiple files from the same station, change the extension, i.e., xxxxxxx1.w1.da1, da2, etc. Similarly name hourly heights data file as xxxxxxx.w2.dat; high and low data files as xxxxxxx.w3.dat; monthly means data file as xxxxxxx.w5.dat; and station datum data file as xxxxxxx.w7.dat
	3. Check the begin and end dates of data submitted with dates of shoreline mapping operations, or project duration for special projects.
	4. Check data continuity.

J. Transmittal Letter

	1. Transmittal letter attached with current contractor address, phone number and email.
--	---

K. All Documentation Enclosed in Tide Level Envelope (NOAA Form 75-29A)

	1. Leave "sheets" box blank, complete other information in title boxes.
	2. Verified completed with signature by contractor and include date.

Figure 1.9. Project Documentation and Data Check-off List

1.5.2 Water Level Data

The final observed water level measurements shall be reported as heights in meters to three decimal places (i.e. 0.001 m). All heights shall be referenced to station datum and shall be referenced to UTC or GMT. The contractor shall provide the water level data in the format specified below from the water level gauges installed.

The original raw water level data and the correctors used to convert the data to chart datum shall be retained until notified in writing or at least three years after the survey is completed. All algorithms and conversions used to provide correctors shall be fully supported by the calibrations, maintenance documentation, leveling records, and sound engineering/oceanographic practices. Factors used to convert the measured data (e.g. pressure to water level heights) shall be maintained for the entire water level collection period and reported.

All digital water level and ancillary data shall be transmitted to CO-OPS in a format dependent on the DCP configuration. If GOES satellite is used for NOAA in-house surveys, the data shall be transmitted and received using the NOS compressed pseudo binary format (see NGWLMS GOES Message Formatting, Libraro, January 2003 at the following url: http://tidesandcurrents.noaa.gov/publications/newgoes_format.pdf). These satellite messages are then decoded by NOS DMS upon receipt from NESDIS before further processing and review by CORMS can be completed. If satellite transmission configurations cannot be installed, the data shall be manually downloaded from the DCP and submitted to NGS, as shown in the format below, in a digital format, on CD-ROM, or by email as an ASCII data attachment.

Six-minute water level data download files shall be named in the following format: xxxxxxxy.w1.dat, where xxxxxxx is the seven digit station number, y is the DCP number (usually 1), w1 is the product code for 6-minute data, and dat is the extension (Use t = 2,3...if more than one file is from the same station and DCP). This is the format needed when the data is loaded into DMS.

Multiple DCP may have been used to collect 6-minute water level data for a particular site, and backup or redundant DCP data may be used to fill the gap in the primary DCP data, but, water level data shall be submitted for a single DCP (numbered as 1). When data from more than one DCP is used to fill the gap, care should be taken to apply the proper correctors (such as gain and offsets, or appropriate staff constants for each DCP/sensor) so that all the 6-minute water level data and the processed products such as hourly heights, high and low data, monthly means data, and station shall be placed on the station datum.

Each input record (including the final record) ends with a carriage return and excludes any extraneous characters such as trailing blank spaces for all types of water level data (6-minute water level data, hourly height, high/low, monthly means, and station datum).

The 6-minute interval data (acoustic sensor and pressure sensor examples follow) shall have the following format for CO-OPS database to accept.

1.5.2.1 Acoustic Sensor Data (XXX.ACO format)

Column 1- 7 Station ID (7 digits, assigned in the project instructions)
Column 8- 8 1 (DCP number, use 2, 3 , etc., for additional DCPs)
Column 9-19 Date (MMM DD YYYY format, e.g. JAN 01 1998)
Column 20-20 Blank
Column 21-22 Hours in 24 hour format (i.e. 00, 01,, 23)
Column 23-23 : (colon)
Column 24-25 Minutes (00,06,12, . . . , 54)
Column 26-32 Data value in millimeters, right justified, (e.g. 1138)
Column 33-38 Sigma (standard deviation in millimeters in integer format)
Column 39-44 Outlier (integer format)
Column 45-50 Temperature 1 (tenth of degrees C in integer format)
Column 51-56 Temperature 2 (tenth of degrees C in integer format)
Column 57-58 Sensor type (A1 for acoustic type)
Column 59-60 blank
Column 61-61 Data Source (S for Satellite, D for Diskette)

Sample data:

```
85169901AUG 17 2007 05:00 1138 23 0 308 297A1 D
85169901AUG 17 2007 05:06 1126 26 0 308 298A1 D
85169901AUG 17 2007 05:12 1107 26 1 309 298A1 D
```

1.5.2.2 Pressure Sensor or Generic Data (XXX.BWL format)

Column 1- 7 Station ID (7 digits, assigned in the project instructions)
Column 8- 8 1 (DCP number, use 2, 3 , etc., for additional DCPs)
Column 9-19 Date (MMM DD YYYY format, e.g. JAN 01 1998)
Column 20-20 Blank
Column 21-22 Hours in 24 hour format (i.e. 00, 01, . . . , 23)
Column 23-23 : (colon)
Column 24-25 Minutes (00-54)
Column 26-32 Data value in millimeters, right justified, (e.g. 1138)
Column 33-38 Sigma (standard deviation in millimeters in integer format)
Column 39-44 Outlier (integer format)
Column 45-50 Sensor temperature (tenth of degrees C in integer format)
Column 51-52 Sensor type (Z1 for generic or pressure)
Column 53-53 blank
Column 54-54 Data Source (S for Satellite, D for Diskette)

Sample data:

```
85169901AUG 17 2007 05:00 1138 23 0 308Z1 D
85169901AUG 17 2007 05:06 1126 26 0 308Z1 D
85169901AUG 17 2007 05:12 1107 26 1 309Z1 D
```

Note: pressure data must be accompanied by documented staff observations as listed in Section 1.2.4.2, if applicable.

1.5.2.3 Tabulations and Tidal Datums

For contract surveys, the contractor shall provide digital tabulations of staff/gauge differences, hourly heights, high and low waters, monthly means, and water level datums for the entire time series of observations from each water level station. Along with the final contractor computed tidal datums, the contractor shall provide copies of the tide-by-tide and/or monthly mean simultaneous comparison sheets from which the final tidal datums were determined. Audit trails of data edits and gap-filling shall be summarized and provided also.

The digital tabulation files for hourly heights, high and low waters, monthly means, and station datum shall have the following formats:

Each input record (including the final record) ends with a carriage return and excludes any extraneous characters such as trailing blank spaces for all types of water level data (6-minute water level data, hourly height, high/low, monthly means, and station datum).

1.5.2.4 Hourly Height data Format

Column 1- 7 Station ID (7 digits, assigned in the project instructions)
Column 8- 8 Blank
Column 9-16 Date (YYYYMMDD format, e.g. 20070120)
Column 17-17 Blank
Column 18-19 Hours (2 digits 00-23, use leading zeros)
Column 20-20 : (colon)
Column 21-22 Minutes (2 digits 00-54, use leading zeros)
Column 23-23 Blank
Column 24-30 Water level value in meters (F7.3 format, e.g. 123.456)

Sample data:

9414290 20040101 00:00 123.456

Hourly height data file shall be named in the following format: xxxxxxx.w2.dat, where xxxxxxx is the seven digit station number, w2 is the product code for the hourly heights data, and dat is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

1.5.2.5 High/Low Data Format

Column 1- 7 Station ID (7 digits, assigned in the project instructions)
Column 8- 8 Blank
Column 9-16 Date (YYYYMMDD format, e.g. 20070120)
Column 17-17 Blank
Column 18-19 Hours (2 digits 00-23, use leading zeros)
Column 20-20 : (colon)
Column 21-22 Minutes (2 digits 00-54, use leading zeros)
Column 23-23 Blank
Column 24-30 Water level value in meters (F7.3 format, e.g. 123.456)
Column 31-31 Blank
Column 32-33 Water level high/low type (H, L, HH, or LL)

Sample data:

9414290 20040101 00:00 123.456 HH

Definition of Acronym:

H: Higher low water level value
L: Lower high water level value
HH: Higher high water level value
LL: Lower low water level value

High and low data file shall be named in the following format: xxxxxxx.w3.dat, where xxxxxxx is the seven digit station number, w3 is the product code for the high/low data, and dat is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

1.5.2.6 Monthly Mean Data Format

Column 1- 7 Station ID (7 digits, assigned in the project instructions)
Column 8- 8 Blank
Column 9- 12 Year (YYYY format, e.g. 2007)
Column 13- 13 Blank
Column 14- 15 Month (in 2 digits 01-12, use leading zeros)
Column 16- 16 Blank
Column 17- 23 MHHW in meters (F7.3 format, e.g. 123.456)
Column 24- 24 Blank
Column 25- 31 MHW in meters (F7.3 format, e.g. 123.456)
Column 32- 32 Blank
Column 33- 39 DTL in meters (F7.3 format, e.g. 123.456)
Column 40- 40 Blank
Column 41- 47 MTL in meters (F7.3 format, e.g. 123.456)
Column 48- 48 Blank
Column 49- 55 MSL in meters (F7.3 format, e.g. 123.456)
Column 56- 56 Blank
Column 57- 63 MLW in meters (F7.3 format, e.g. 123.456)
Column 64- 64 Blank
Column 65- 71 MLLW in meters (F7.3 format, e.g. 123.456)
Column 72- 72 Blank
Column 73- 79 GT in meters (F7.3 format, e.g. 123.456)
Column 80- 80 Blank
Column 81- 87 MN in meters (F7.3 format, e.g. 123.456)
Column 88- 88 Blank
Column 89- 95 DHQ in meters (F7.3 format, e.g. 123.456)
Column 96- 96 Blank
Column 97-103 DLQ in meters (F7.3 format, e.g. 123.456)
Column 104-104 Blank
Column 105-111 Maximum Water Level in meters (F7.3 format, e.g. 123.456)
Column 112-112 Blank
Column 113-120 Maximum Water Level Date (in YYYYMMDD format, last occurrence)
Column 121-121 Blank
Column 122-123 Maximum Water Level Hour (2 digits 00-23, use leading zeros)
Column 124-124 : (colon)
Column 125-126 Maximum Water Level Minute (2 digits 00-54, use leading zeros)
Column 127-127 Blank
Column 128-128 Maximum Water Level occurrences (1 digit)
Column 129-129 Blank
Column 130-136 Minimum Water Level in meters (F7.3 format, e.g. 123.456)
Column 137-137 Blank

Column 138-145 Minimum Water Level Date (in YYYYMMDD format, last occurrence)
Column 146-146 Blank
Column 147-148 Minimum Water Level Hour (2 digits 00-23, use leading zeros)
Column 149-149 : (colon)
Column 150-151 Minimum Water Level Minute (2 digits 00-54, use leading zeros)
Column 152-152 Blank
Column 153-153 Minimum Water Level occurrences (1 digit)

Sample data (with column ruler):

```

      0      0      0      0      0      0      0      0
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
9414290 2004 01 123.456 123.456 123.456 123.456 123.456 123.456 123.456 123.456

      0      1      1      1      1      1      1
      9      0      1      2      3      4      5
123456789012345678901234567890123456789012345678901234567890123
123.456 123.456 123.456 123.456 20040101 00:00 1 123.456 20040101 00:00 1
```

Definition of Acronym:

MHHW	Mean Higher High Water
MHW	Mean High Water
DTL	Diurnal Tide Level
MTL	Mean Tide Level
MSL	Mean Sea Level
MLW	Mean Lower Water
MLLW	Mean Lower Low Water
GT	Great Diurnal Tide Range
MN	Mean Range of Tide
DHQ	Diurnal High Water Inequality
DLQ	Diurnal Low Water Inequality
MAX_WL	Maximum Water Level during the Month measurement period
MAX_DATE	Date of Maximum Water Level
MAX_HOUR	Hour of Maximum Water Level
MAX_MIN	Minute of Maximum Water Level
MAX_OCCUR	Number of occurrences during the month the Water Level meets the
MAX_WL	
MIN_WL	Minimum Water Level during the Month measurement period
MIN_DATE	Date of Minimum Water Level
MIN_HOUR	Hour of Minimum Water Level
MIN_MIN	Minute of Minimum Water Level
MIN_OCCUR	Number of occurrences during the month the Water Level meets the
MIN_WL	

Monthly Means data file shall be named in the following format: xxxxxxx.w5.dat, where xxxxxxx is the seven digit station number, w5 is the product code for the monthly means data, and dat is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

1.5.2.7 Station Datum Data Format

Column 1- 7 Station ID (7 digits, assigned in the project instructions)
Column 8- 16 Blank
Column 17- 23 MHHW in meters (F7.3 format, e.g. 123.456)

Column 24- 24 Blank
 Column 25- 31 MHW in meters (F7.3 format, e.g. 123.456)
 Column 32- 32 Blank
 Column 33- 39 DTL in meters (F7.3 format, e.g. 123.456)
 Column 40- 40 Blank
 Column 41- 47 MTL in meters (F7.3 format, e.g. 123.456)
 Column 48- 48 Blank
 Column 49- 55 MSL in meters (F7.3 format, e.g. 123.456)
 Column 56- 56 Blank
 Column 57- 63 MLW in meters (F7.3 format, e.g. 123.456)
 Column 64- 64 Blank
 Column 65- 71 MLLW in meters (F7.3 format, e.g. 123.456)
 Column 72- 72 Blank
 Column 73- 79 GT in meters (F7.3 format, e.g. 123.456)
 Column 80- 80 Blank
 Column 81- 87 MN in meters (F7.3 format, e.g. 123.456)
 Column 88- 88 Blank
 Column 89- 95 DHQ in meters (F7.3 format, e.g. 123.456)
 Column 96- 96 Blank
 Column 97-103 DLQ in meters (F7.3 format, e.g. 123.456)
 Column 104-104 Blank
 Column 105-111 Maximum Water Level in meters (F7.3 format, e.g. 123.456)
 Column 112-112 Blank
 Column 113-120 Maximum Water Level Date (in YYYYMMDD format, last occurrence)
 Column 121-121 Blank
 Column 122-123 Maximum Water Level Hour (2 digits 00-23, use leading zeros)
 Column 124-124 : (colon)
 Column 125-126 Maximum Water Level Minute (2 digits 00-54, use leading zeros)
 Column 127-127 Blank
 Column 128-128 Maximum Water Level occurrences (1 digit)
 Column 129-129 Blank
 Column 130-136 Minimum Water Level in meters (F7.3 format, e.g. 123.456)
 Column 137-137 Blank
 Column 138-145 Minimum Water Level Date (in YYYYMMDD format, last occurrence)
 Column 146-146 Blank
 Column 147-148 Minimum Water Level Hour (2 digits 00-23, use leading zeros)
 Column 149-149 : (colon)
 Column 150-151 Minimum Water Level Minute (2 digits 00-54, use leading zeros)
 Column 152-152 Blank
 Column 153-153 Minimum Water Level occurrences (1 digit)

Sample data (with column ruler):

0	0	0	0	0	0	0	0
1	2	3	4	5	6	7	8
1234567890123456789012345678901234567890123456789012345678901234567890							
9414290	123.456	123.456	123.456	123.456	123.456	123.456	123.456
0	1	1	1	1	1	1	
9	0	1	2	3	4	5	
1234567890123456789012345678901234567890123456789012345678901234567890123							
123.456	123.456	123.456	123.456	20040101	00:00	1	123.456
				20040101	00:00	1	

Definition of Acronyms for Station Datum data are same as that for the Monthly Mean data.

Station datum data file shall be named in the following format: xxxxxxx.w7.dat, where xxxxxxx is the seven digit station number, w7 is the product code for the station datum data, and dat is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

If the Greenwich high water interval (HWI) and Greenwich low water interval (LWI) are available, then contractor shall provide that information in F5.2 format (e.g. xx.xx) and that file shall be named as station#.GWI.txt. Generally the interval values should be between 0.0 and 12.41.

1.5.3 Submission and Deliverables – Documentation and Time lines

The check-off list in [Figure 1.9](#) (in Section 1.5.1) shall be used to check and verify the documentation that is required for submission. All documentation, water level data, processed data including hourly height, high/low data, monthly means data, and station datums data, GPS OPUS results, other reports as required, shall be forwarded within 15 business days of the removal of the water level stations/gauges, or as specified in the contract.

All data and documentation shall be submitted to NGS. All data and documentation that is submitted shall be retained by the contractor for a period of not less than three years or as stipulated in the contract, whichever is longer.

All data and documentation shall be submitted in digital format. Please refer to Section 1.5.1, 1.5.2, and below for details about various data and documentation.

The station documentation generally includes, but is not limited to the following:

- (1) Transmittal letter (PDF format)
- (2) E-Site Report, or Water Level Station Xpert Site Report, or Tide Station Report (E-Site report in web based electronic format, Water Level Station Xpert Site Report or Tide Station report in Microsoft Excel format)
- (3) Google Chartlet, or NOAA Chartlet with chart number or map name and scale shown. (JPEG format)
- (4) Name of the U.S. Geological Survey quadrangle map (7.5 seconds interval) indicating the exact location of the station, with map name and scale shown (JPEG format)
- (5) Sensor test worksheet (PDF format)
- (6) Sensor elevation drawing (PDF format) showing sea floor, pier elevation, and sensor elevation if the sensor is mounted vertically.
- (7) Water level transfer form (for Great Lakes stations only in PDF format)
- (8) Barometer Installation Worksheet (for Great Lakes stations only in PDF format)
- (9) Bench mark sketch (PDF format) – Large-scale bench mark location sketch of the station site showing the relative location of the water level gauge, staff (if any), bench marks, and major reference objects found in the bench mark descriptions. The bench mark sketch shall include an arrow indicating north direction, a title block, and latitude and longitude (obtained from hand-held GPS receiver) of the gauge.
- (10) Bench mark descriptions with handheld GPS coordinates (d/m/s.x format), and “Station To

- Reach” statement (in Microsoft Word format) (Refer to User’s Guide for Writing Bench Mark Descriptions, NOAA/NOS, Updated January 2003).
- (11) Digital photographs of bench mark disk - close-up and eye level view of setting, bench mark locations from two different (perpendicular) horizontal cardinal directions, station, DCP, equipment, underwater components, and vicinity (JPEG format)
 - (12) Levels (raw) (electronic files) including leveling equipment information and field notes of precise leveling, if applicable.
 - (13) Abstract of precise leveling (electronic format)
 - (14) Datum offset computation worksheet or Staff/Gauge difference work sheet as appropriate showing how sensor “zero” measurement point is referenced to the bench marks.
 - (15) Staff to gauge observations, if applicable (in Microsoft Excel format)
 - (16) Calibration certificates for Invar leveling rods, if applicable (in PDF format)
 - (17) Calibration records for sensors, if applicable (in PDF format)
 - (18) Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable (in PDF format)
 - (19) Other information as appropriate, or as specified in the contract (in PDF format)
 - (20) Water level data download in specified format
 - (21) GPS Deliverables - the OPUS DB datasheet and four photos of the GPSBM in electronic format for each observation for each water level station as described in the User’s guide for GPS Observations At Tide and Water Level Bench Marks.

For long term water level stations (more than 1 year), the bench mark sketch, chartlet, and "To Reach" statement need only be submitted if those items have been revised after the initial submission. When using the electronic/barcode system, the data of the abstract and bench mark description or recovery notes shall be submitted. For optical levels, submit the raw levels and the leveling abstract.

For submission in electronic format, the station documentation shall be organized by various folders under the main station number folder, and then pertinent information shall be placed in the various folders and submitted on a digital media such as DVD/CD-ROM etc.

Here is an example of submission of the electronic folders for San Francisco tide station:

9414290 San Francisco FY 08 Installation

- /Transmittal letter
- /Calibration records for sensors, if applicable
- /Site Report or tide station report
- /Chartlet and USGS Quad maps
- /Sensor test worksheet
- /Sensor elevation drawing
- /Bench mark sketch
- /“Station To Reach” statement
- /Bench mark descriptions
- /Photographs of bench marks, station, DCP, equipment, and vicinity in digital format
- /Levels (raw) (electronic files) and field notes of precise leveling
- /Abstract of precise leveling

- /Staff to gauge observations, if applicable
- /Datum offset computation worksheet or Staff/Gauge difference work sheet (elevation of sensor zero measurement point referenced to bench marks)
- /Calibration certificates for Invar leveling rods, if applicable
- /Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable
- /Other information as appropriate, or as specified in the contract
- /Water level data (6-minute, hourly heights, high/low, monthly means, station datum)
- /GPS data and documentation

Submit required GPS deliverables OPUS results and 4 photos of GPSBM on a separate digital media, such as DVD/CD-ROM, FTP sites, etc. For example, GPS submission for San Francisco tide station will be as follows:

- 9414290 San Francisco FY 08 Annual Inspection
- /GPS deliverables
- /Photos of GPSBM

Submit the completed station package to:

Mr. George Leigh
Contracting Officers Representative
NOAA/NOS/National Geodetic Survey
SSMC 3, Station # 8609
1315 East-West Highway
Silver Spring, MD 20910-3281
Tel # 301-713- 3167

1.6 Guidelines and References

References for the water level measurement and leveling requirements issued by the NOS Center of Operational Oceanographic Products and Services (CO-OPS) and the National Geodetic Survey (NGS) are listed below.

Most of these documents are available on CO-OPS web site at <http://tidesandcurrents.nos.noaa.gov>.

1. Next Generation Water Level Measurement System (NGWLMS) Site Design, P repairation, and Installation Manual, NOAA/NOS, January 1991.
2. User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, NOAA/NOS, dated October 1987.
3. User's Guide for Writing Bench Marks Descriptions, NOAA/NOS, Updated January 2002.
4. User's Guide for Electronics Levels, NOAA/NOS, updated January 2003.
5. User's Guide for 8200 Bubbler Gauges, NOAA/NOS, updated February 1998.

6. User's Guide for 8200 Acoustic Gauges, NOAA/NOS, updated August 1998.
7. User's Guide for 8210 Bubbler Gauges, NOAA/NOS, updated February 2001.
8. User's Guide for GPS Observations At Tide and Water Level Station Bench Marks, NOAA/NOS, updated November 2008.
9. Tidal Datums and Their Applications, Special Publication No. CO-OPS 1, NOAA/NOS, June 2000.
10. Manual of Tide Observations, U.S. Department of Commerce, Publication 30-1, Reprinted 1965.
11. Tidal Datum Planes, U.S. Department of Commerce, Special Publication No.135, Marmer 1951.
12. Tide and Current Glossary, U.S. Department of Commerce, NOAA, NOS, October 1989.
13. Standing Project Instructions: Great Lakes Water Levels, June 1978.
14. NOAA Technical Report NOS 64 "Variability of Tidal Datums and Accuracy in Determining Datums from Short Series of Observations", Swanson, 1974.
15. Data Quality Assurance Guidelines for Marine Environmental Programs, Robert J. Farland, Office of Ocean Engineering, NOAA, March, 1980.
16. System Development Plan, CORMS: Continuous Operational Real-Time Monitoring System, NOAA Technical Report NOS OES 014, U.S. Department of Commerce, NOAA, NOS February, 1997.
17. NGWLMS GOES MESSAGE FORMATTING, Phil Libraro, 1/2003.
18. Computational Techniques for Tidal Datums, NOAA Technical Report NOS CO-OPS 2, U.S. Department of Commerce, NOAA, NOS, DRAFT December 1998.
19. Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee, September 1984.
20. NOAA Technical Memorandum "NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards 2 cm and 5 cm), Version 4.3", November 1997.
21. Geodetic Leveling, NOAA Manual NOS NGS 3, U.S. Department of Commerce, NOAA, National Ocean Survey, August, 1981.
22. Xpert Operations and Maintenance Manual, October 2006.